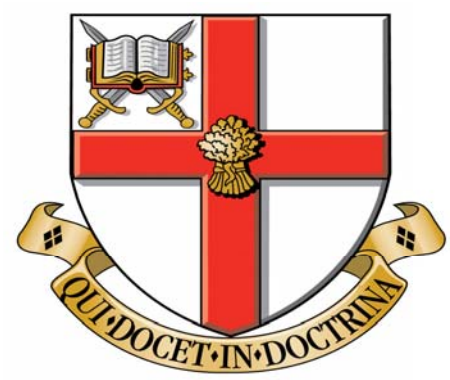


University of Chester

A systematic review of the effects of dieting on food cravings in an overweight or obese population

Name: Angela Meadows

Submission date: 30th October 2012

Acknowledgements

I would like to extend a special thank you to the various cravings researchers who patiently answered all my requests for clarification on their research, as well as providing additional information and access to difficult-to-obtain papers. On occasion, the additional information they provided resulted in their work being excluded from the present review, but was no less valuable for this. In particular, and in alphabetical order, I would like to thank Professor Frank Greenway, Professor Marion Hetherington, Dr Julia Hormes, Dr Timo Hursti, Professor Marco Innamorati, Professor Corby Martin, Dr Susan Roberts, Professor Sarah Sitton, and Professor Werner Stritzke. Without their assistance, this review would not have been possible.

I would also like to thank my supervisor, Dr Stephen Fallows, for support throughout, and Dr Karla Hemming and Dr Richard Riley from the University of Birmingham, for statistical advice. Finally, I would like to thank my husband for his constant encouragement and for provision of copious amounts of coffee during the write up stage of this review.

Abstract

Objectives: To systematically search and evaluate the literature on the effects of weight-loss dieting on food cravings in overweight or obese adults.

Methods: Studies were obtained from searches of multiple electronic bibliographic databases. Inclusion criteria were: (1) adult participants (18 years and older), classified as overweight or obese by body mass index (BMI ≥ 25 kg/m^2) at baseline, and currently following a hypocaloric diet for the purposes of weight loss; (2) a non-dieting overweight/obese control; (3) at least one outcome measure relating to frequency, intensity, or behavioural dimensions of food cravings. No restrictions on study design were made. Relevant studies were assessed for risk of bias and study characteristics, details of dietary intervention, patient details, and cravings outcomes were extracted.

Results: Eight studies met the inclusion criteria and were included in the review, although none provide longitudinal comparisons of the impact of dieting versus non-dieting in an exclusively overweight population. Wide heterogeneity between studies in terms of design, dietary interventions and outcome measures used precluded pooling of data. Overall, low-calorie dieting appeared to have little or no effect on frequency, intensity, or type of cravings, although severe caloric restriction did appear to reduce the frequency of both general and intense cravings. There is some evidence that restricted foods are craved less, rather than more, during weight-loss dieting.

Conclusions: The data do not support lay perceptions that dieting increases food cravings; however, these findings are based on a small number of studies, and methodological issues limit the conclusions that can be drawn from these studies.

Originality declaration

This work is original and has not been previously submitted in support of a Degree, qualification or other course.

Signed ……..

Date ……..

Table of Contents

List of Tables

List of Figures

Abbreviations

BMI	Body Mass Index
COEQ	Control Of Eating Questionnaire
FCI	Food Craving Inventory
FCQ (-T/S)	Food Craving Questionnaire (Trait/State version)
GL	Glycaemic load
HAES	Health At Every Size®
ITT	Intent to treat
IWL	Intentional weight loss
LCD	Low-calorie diet
LCaD	Low-carbohydrate diet
LFD	Low-fat diet
PP	Per protocol
RCT	Randomised, controlled trial
SD	Standard deviation
VAS	Visual analogue scale
VLCD	Very-low-calorie diet

Introduction

Obesity is widely perceived to be a condition caused by ongoing excessive energy intake beyond physiological need. Reducing energy intake should therefore result in weight loss. However, it has been hypothesised that body adiposity is homeostatically defended; therefore, any attempts to reduce calorie consumption over the long-term will be met with a paradoxical rebound in appetitive drive (Speakman et al., 2011). Certainly, the vast majority of dieters are unable to maintain weight loss over an extended period, with a large proportion gaining back more than originally lost (Mann et al., 2007). The mechanism by which this rebound occurs is not well understood, but one possible explanation is that the act of restriction itself may cause food cravings, due to either physiological or psychological deprivation (Polivy, Coleman, & Herman, 2005). Further, several studies have linked cravings with increased food consumption (A. J. Hill & Heaton-Brown, 1994; Weingarten & Elston, 1991). The role of weight-loss dieting in the experience of food cravings in an overweight or obese population is therefore of interest in the design and implementation of weight loss interventions.

Definition of 'craving'

Despite the ubiquitous use of the term 'craving' in the lay population, the scientific study of food cravings has suffered from the absence of an operational definition of the term (Weingarten & Elston, 1990). As with other psychological constructs, such as hunger and palatability, cravings are an abstract, subjective experience that likely lie on a continuum rather than having a stochastic presentation (Weingarten & Elston, 1990). As a result, objective characterisation and measurement of

cravings is fraught with difficulties, and, consequently, many experimental studies have relied upon a pragmatic, lay definition of the term, whereby cravings are most often characterised as an *intense* desire for a *specific* substance.

Prevalence of food cravings

A number of studies have found food cravings to be very commonplace in the general population, with some reports suggesting up to 97% of people have experienced cravings at least once (Weingarten & Elston, 1991). However, prevalence of food cravings is strongly influenced by the stringency of definition applied. For example in one study of 101 randomly selected adult women, 58% reported ever having experienced a food craving (Gendall, Joyce, & Sullivan, 1997). However, when a measure of intensity was included, this number was reduced to 42% for moderate/strong intensity and only 21% when strong intensity was stipulated. When the definition of 'craving' was extended to include up to three core features of cravings, namely difficulty resisting the craved food, anxiety or discomfort with abstention from the craved food, and change in speed of consumption if the craved food were eaten, further reductions in prevalence were observed. Using the most stringent definition – strong intensity plus all three core features – only 4% of the sample reported having experienced food cravings of this nature. Thus, the significance of definition used on research outcomes should not be underestimated.

In Western countries, the most commonly craved foods tend to be high-fat, energy dense, and/or sweet, with chocolate being reported as the most frequently craved food in a number of studies (Gendall, et al., 1997; A. J. Hill, Weaver, & Blundell,

1991; Weingarten & Elston, 1991). However, the extent and types of cravings appear to be influenced by age, gender, and culture (Komatsu, 2008; Osman & Sobal, 2006; Parker, Kamel, & Zellner, 2003; Pelchat, 1997; Weingarten & Elston, 1991).

Assessment of food cravings

Most early studies of food craving relied on subjective reports of cravings using arbitrary scales, and many did not take into account the intensity of desire. The search for more objective measures of cravings has included the use of physiological measures such as heart rate, skin conductance, blood pressure, and salivary secretions. However, these processes are not well-correlated with other measures of cravings (Weingarten & Elston, 1990), and are open to obvious confounding as their measurement in a clinical setting may well result in increased anxiety in the subjects.

More recently, attempts to increase the reliability and reproducibility of experimental data on cravings have led to the design and psychometric validation of a number of general and food-specific assessment instruments. For example, the Food Craving Inventory (FCI) asks about the frequency of "intense", "difficult to resist" desire for 28 specific food items in the previous month (M. A. White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002), but does not explore other parameters of food cravings. In contrast, the Food Craving Questionnaire – Trait (FCQ-T) and State (FCQ-S) versions (Cepeda-Benito, Gleaves, Williams, & Erath, 2000) comprise nine subscales, which in addition to assessing frequency and intensity (FCQ-S only) of cravings and expectations of positive or negative reward,

also incorporates measures of hunger, affective responses to actual consumption, and speed of consumption when craved foods are eaten. Whilst speed of consumption has been shown to correlate with cravings in alcoholism (Rankin, Hodgson, & Stockwell, 1979), these latter measures are problematic as not all cravings are associated with subsequent consumption. A modified version of these questionnaires has been published, in which a shorter, four-factor structure was identified, comprising preoccupation with food in general, expectation of loss of control on eating, expectation of positive affect or reduction in negative affect, and cravings associated with emotions (Nijs, Franken, & Muris, 2007). Similarly, the Questionnaire on Craving for Sweet or Rich Foods assesses frequency and intensity of food cravings within specific food groups, as well as expectations of positive or negative affect and perceived ability to control consumption if the craving were satisfied (Toll, Katulak, Williams-Piehota, & O'Malley, 2008). These scales therefore avoid the problem of linking craving experience with actual consumption.

It is worth noting that the FCQ-T does not provide a definition of the term 'craving' and allows for subjective interpretation throughout. Psychometric evaluation of FCQ-T failed to support the concept of trait 'craving' as an '*intense desire to eat*'. The authors hypothesise that it is food specificity that is significant, whereas intensity may be state-specific (Cepeda-Benito, et al., 2000).

Food cravings and dieting

The seminal 'Minnesota Experiment' conducted during the second world war by Ancel Keys and colleagues found that when previously healthy young men underwent severe food deprivation (semi-starvation), they became increasingly

preoccupied, even obsessed, with food, experienced a range of negative psychological effects, including cognitive impairment and high levels of anxiety and irritability, and became apathetic and lethargic. Of particular interest, when normal feeding was resumed, these previously non-pathological eaters exhibited loss of control around food, episodes of binge eating, and even theft, hiding, and hoarding of food (Keys, Brozek, Henschel, Mickelsen, & Taylor, 1950). Naturalistic evidence from prisoners of war or other populations undergoing severe food shortages also suggests that excessive, uncontrolled consumption is common once food supplies are restored, and continues beyond weight restoration (Keys, et al., 1950; Polivy, 1996).

It is this evidence on the physical and psychological effects of food deprivation that inform much of the perception of the effects of dieting on food cravings and consumption. Indeed, the general public perception is that dieting increases food cravings; however, experimental evidence in support of this hypothesis is equivocal. It is worth noting that the effects of food deprivation in a healthy weight population with no interest in weight loss is likely to have different physiological and psychological effects than in a population whose weight is above desired norms and in whom weight loss would not reduce them to an underweight state. In the former population, it would seem that significant increases in hunger and motivational drive towards food consumption and ensuring food security would likely be an adaptive survival response, as would an 'overshoot' effect, beyond baseline weight, to protect against any future deprivation. Consistent with this hypothesis, the increased preoccupation with food and appetitive drive observed in the Keys experiment appear to have more in common with extreme hunger than in

cravings for specific foods. The majority of subjects 'craved' food in general, and where specific foods were mentioned, these did not consistently belong to any particular macronutrient or micronutrient-rich food group, but rather tended towards a range of high-energy-density foods, such as sweets, cheese, and nuts (Keys, et al., 1950). Thus, the physical and psychological consequences of semi-starvation may not be generalisable to an overweight dieting population.

Indeed, even in a non-starved population, differences have been identified in the experience of cravings between overweight and normal weight individuals. For example, obese individuals were found to be more likely to crave high-fat foods on the FCI than were normal weight individuals (M. A. White, et al., 2002). Whether there is something inherent in the biology of overweight individuals that causes this relationship is unclear. Other possibilities include a predisposition to craving high-fat foods being causally related to the development of overweight, or conversely, that overweight individuals with a history of chronic dieting and thus self-imposed abstinence from such foods may be increasingly likely to respond to ubiquitous environmental cues for such foods than non-deprived individuals (Lowe & Butryn, 2007). Whilst the mechanisms underlying such differences have yet to be elucidated, there is clearly a disparity in the experience of cravings between normal weight and overweight individuals.

A majority of the food craving literature has derived from experimental studies of food cravings in normal weight college populations, and thus may not be applicable to a weight-loss setting. Other studies have compared cravings in overweight dieters with normal weight non-dieters, again limiting the ability to elucidate the

true effects of the diet itself on food cravings in the overweight population. This omission in significant, as evidence suggests that the experience of cravings in weight-loss dieters correlates with adherence to dietary interventions. One study found that carbohydrate cravers were almost three times more likely to drop out of a very-low-calorie-diet (VLCD) weight-loss programme than were non-cravers (Sitton, 1991), and carbohydrate cravings are commonly blamed for failure of diets in overweight women (Bjorvell, Ronnberg, & Rossner, 1985). Cravings have also been cited as the most common reason for non-adherence in controlled feeding studies (Hall & Most, 2005). In addition, previous experience of cravings while dieting has been positively associated with baseline body mass index (BMI) in over 1000 obese participants in the Diabetes Prevention Program (Delahanty et al., 2002), although the direction of causality cannot be inferred from these data.

Yet, while some studies have reported increased frequency of food cravings in individuals concerned with weight control (Gendall, et al., 1997), not all studies have found this effect (Weingarten & Elston, 1991). It is worth noting, however, that not all individuals concerned with weight control are currently overweight. Dieting for weight maintenance is more common than dieting for weight loss (A. Hill, 2002). Massey & Hill (2012) distinguished between current weight-loss dieters, individuals who 'watched what they ate' in order not to gain weight, and non-dieters, finding significant differences in craving experiences between the groups. Watchers had a similar BMI to non-dieters (24.3 versus 23.4 kg/m^2), putting both groups in the 'normal weight' range. Nevertheless, both groups reported an 'ideal weight' more than 6 kg below their current weight, indicating significant body dissatisfaction. Mean BMI in the dieting group was 29.1 kg/m^2, and

body dissatisfaction was also higher in this group. Cravings were found to differ between the groups, with 'dieters' experiencing significantly more food cravings in a 7-day period than 'watchers', who in turn experienced more cravings than non-dieters. Food cravings in 'watchers' tended to be for foods they were restricting around half of the time (50.1%), compared with 26.9% in non-dieters and 74.7% in weight-loss dieters. In addition to more frequently craving the foods they were restricting, 'dieters' experienced significantly greater intensity of cravings and difficulty in resisting the cravings than did the other two groups. The distinction between dieting for weight loss or for weight maintenance is rarely made in the literature, and may impact on the findings of studies of self-reported dieters where BMI is not measured.

Interpretation of the cravings literature is also complicated by the widespread use of measures of dietary restraint as a proxy for dieting, with reports on the experience of food cravings between high- and low-restrained eaters producing conflicting results (A.J. Hill, 2007). However, dietary restraint is a poor indication of current dieting, and is only weakly correlated with energy intake (Stice, Sysko, Roberto, & Allison, 2010). Further, a recent study of over 1000 post-menopausal women found that while current dieting was positively associated with BMI, increased dietary restraint was associated with lower BMI, and concluded that dieting and dietary restraint were not equivalent concepts (Rideout & Barr, 2009). Massey & Hill (2012) found that while dietary restraint correlated with craving frequency, it did not account for differences in craving intensity or resistibility between dieters and non-dieters/'watchers'.

Interestingly, in their validation of the FCQ in German, Meule et al. (2012) found no differences in state cravings between self-reported successful and unsuccessful dieters, suggesting that experiences of cravings during dieting do not differ between those who go on to lose weight and those who do not, but that successful dieters may instead be better able to resist cravings. However, the sample population in this study was predominantly students, with a mean BMI of 22.3 kg/m^2, and the applicability of these findings to a clinical population are uncertain. In addition, 'dieting' status was ascertained using the Restraint Scale 'Concern for Dieting' subscale (Herman & Polivy, 1980), rather than actual current caloric restriction. The Concern for Dieting Scale has been demonstrated not to significantly correlate with actual calorie restriction in a sample of overweight dieters (Williamson et al., 2007). A further limitation of this study is that 'successful' dieting was assessed by self-perception, rather than any objective measure of weight loss.

Why it is important to do this review

Whilst the food cravings literature raises some interesting questions about the experience and importance of this phenomenon in an overweight dieting population, it answers few of them. The majority of studies have used proxy measures for cravings and/or current dieting, making interpretation of the results problematic, and possibly contributing to the inconsistent findings across studies. Further, and importantly, much of the craving literature is based on studies involving undergraduate students or normal weight individuals exposed to a range

of dietary manipulations, and it is not certain that these findings can be generalised to an overweight or obese population.

Whilst the understanding of cravings in general is of scientific interest, and may help direct further research in the field, practical applications of this knowledge are likely to be more significant in a clinical population. Yet, to date, no systematic reviews of the craving literature in an overweight dieting population has been conducted.

Aim

To conduct a systematic review of studies examining the incidence, intensity, or subjective experience of food cravings in overweight or obese adults undergoing caloric restriction for the purpose of weight loss, as compared with overweight or obese non-dieters.

Methods

Inclusion criteria

Details of the inclusion criteria are shown in Table 1. Briefly, experimental studies measuring cravings in overweight or obese adults who were dieting for the purposes of weight loss were included. Studies measuring dietary restraint only, as opposed to current caloric restriction, were excluded. Outcome variables based on proxy measures of cravings were also not included, for the reasons outlined above. As scoping searches indicated a paucity of randomised controlled trials (RCTs), it was decided to include all experimental designs and both between- and within-group comparisons.

Table 1. Inclusion criteria

Study design	Any experimental design
Participants	Adult (≥ 18 years), classified as 'overweight' or 'obese' by BMI (BMI ≥ 25 kg/m^2)
Intervention	Hypocaloric diet for the purpose of weight loss.
Control	No caloric restriction. Both between-subject and within-subject controls (i.e. before and after studies) were included.
Outcome	At least one measure of frequency, intensity, or behavioural dimension of food cravings.

Search methods

Electronic searches

The following electronic databases were searched:

- MEDLINE (1946 to August Week 1, 2012);
- EMBASE (1974 to Aug 8th, 2012);
- Science Citation Index (1945 to 2012);
- The Cochrane Library: Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, and Health Technology Assessment Database.

Depending on the database, searches were limited to humans and to English language publications where possible. In MEDLINE and EMBASE, a sensitive therapy search limit was applied. Details of the search strategy are reported in Appendix 1.

Searching other resources

The reference lists of review articles and of all included studies were searched in order to find other potentially eligible studies, and subsequent studies citing the included studies were also assessed for relevance. Attempts were made to identify subsequent full-text publications of potentially relevant conference abstracts.

Data collection and analysis

Selection of studies

Titles and abstracts of retrieved studies were assessed for relevance. Full articles were retrieved for further assessment if the information given suggested that the study met the inclusion criteria. When a title/abstract could not be rejected with certainty, the full text of the article was obtained for further evaluation. Authors were contacted where additional information was necessary to make decisions about inclusion or exclusion, or when unpublished subgroup analyses may have provided relevant data.

Data extraction and management

The following data were extracted: (1) General information including title, authors, country, year of publication; (2) Trial characteristics including design, duration, allocation to intervention/control groups, allocation concealment, blinding; (3) Intervention details including nature of dietary restriction and comparison interventions and duration of intervention; (4) Patient details including sampling methods, inclusion and exclusion criteria, total number and number in each treatment arm, gender, age, diagnostic criteria of overweight/obesity, similarity of groups at baseline, assessment of compliance, withdrawals and losses to follow-up; (5) Outcomes assessed and outcome measures used; (6) Results and method of analysis.

Statistical analysis

Where mean values and measures of variance were available for before and after data, effect sizes and 95% confidence intervals were calculated using Cochrane Review Manager (RevMan version 5.1) software. The difference between baseline readings and the first recorded post-baseline time point were used, as changes in cravings measures tend to occur in the early stages of dietary change. Random effects models were applied and effect sizes were expressed as mean differences. Any other ad hoc statistical tests used are reported in the text.

Assessment of risk of bias in included studies

The risk of bias for each study was assessed using The Cochrane Collaboration's Risk of Bias Tool 5.1.0 (The Cochrane Collaboration, 2011). The tool was adapted for assessment of non-randomised studies in line with the recommendations in Deeks et al. (2003). Where subsets of study data were used in this review, the methodological quality of the parent study was assessed, although any additional sources of potential bias pertaining to individual treatment arms were also evaluated.

Results

Search results

The search strategy identified 3992 publications. Following title/abstract review, 143 articles were retrieved for further evaluation. Of these, 10 publications met the inclusion criteria, representing eight distinct studies (Figure 1). Full details of the included studies are presented in Appendix 2. Characteristics of studies excluded at the full-text stage are presented in Appendix 3.

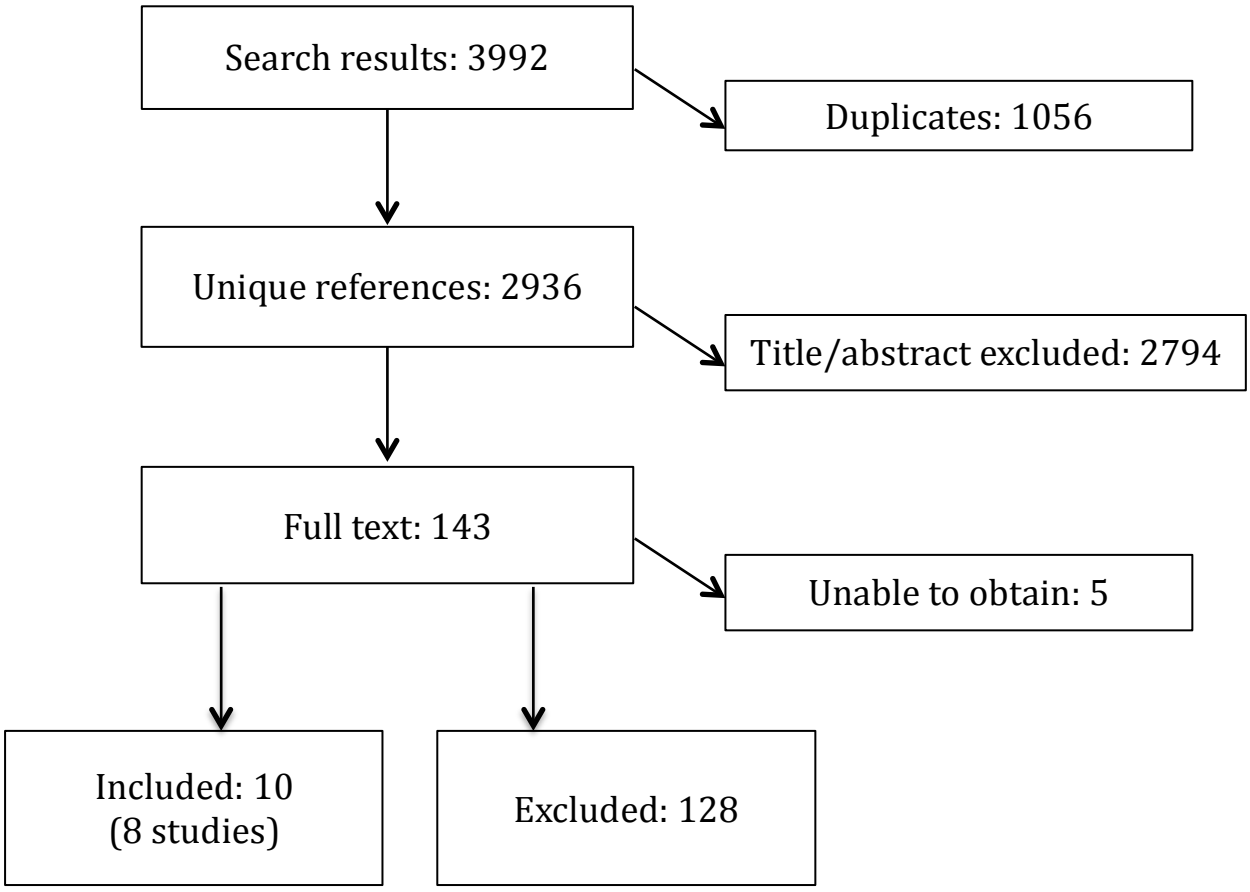


Figure 1. Results of literature search

Included studies

Detailed descriptions of the included studies are reported in Appendix 2. The studies were conducted between 1990 and 2011. Two studies (Gilhooly et al., 2007; Lappalainen, Sjoden, Hursti, & Vesa, 1990) had fewer than 50 participants, three (Fabbricatore, Imperatori, Pecchioli, et al., 2011; Harvey, Wing, & Mullen, 1993; C. K. Martin, O'Neil, & Pawlow, 2006) between 50 and 100, and three (Fabbricatore, Imperatori, Morgia, et al., 2011; Greenway et al., 2010; C.K. Martin et al., 2011) involved over 100 subjects.

Study design

Four of the studies (Gilhooly, et al., 2007; Greenway, et al., 2010; Harvey, et al., 1993; C.K. Martin, Rosenbaum, et al., 2011) were RCTs and four (Fabbricatore, Imperatori, Morgia, et al., 2011a; Fabbricatore, Imperatori, Pecchioli, et al., 2011b; Lappalainen, et al., 1990; C. K. Martin, et al., 2006) were non-randomised comparative studies. However, none provided prospective, longitudinal comparisons of craving measures in dieting and non-dieting overweight/obese adults. Several of the studies had two active intervention arms investigating the relative efficacy of different diet regimens. A further data set represented the placebo arm of a pharmacological plus diet intervention for weight loss. As the purpose of this review was not to compare diets but to assess the effect of dieting versus not dieting, the cravings data were assessed within diet groups rather than between groups. This approach has the effect of violating randomisation in the RCTs, and through no fault of the study authors, reduces the 'level of evidence' in the six longitudinal studies (Gilhooly, et al., 2007; Greenway, et al., 2010; Harvey, et al., 1993; Lappalainen, et al., 1990; C. K. Martin, et al., 2006; C.K. Martin, Rosenbaum,

et al., 2011) to that of uncontrolled before-and-after data, i.e. case series. The remaining two studies provided cross-sectional data (Fabbricatore, Imperatori, Morgia, et al., 2011; Fabbricatore, Imperatori, Pecchioli, et al., 2011).

Participants and setting

Relevant data were available for 1161 participants across the eight studies, although the two largest studies (Greenway, et al., 2010; C.K. Martin, Rosenbaum, et al., 2011) accounted for 781 (67%) of these. Of the eight studies, seven involved samples with a mean BMI in the obese category (range 30.1 to 41.1 kg/m^2), and one had a sample with mean BMI in the overweight category (27.8 kg/m^2).

All were conducted in adults. The mean age of participants ranged from 35.0 to 52.8 years. Based on seven studies, the proportion of female participants was 74% (529/655). The eighth study provided demographic data for the initial randomised sample only, and this group comprised 85% (494/581) women.

All studies were conducted in outpatient settings, including specialist weight management clinics and academic and primary care settings. Recruitment was through a combination of local newspapers, radio announcements, bulletin boards, and physician referrals.

Interventions

Cravings data were available for 12 distinct data sets across the eight studies, representing five different types of dietary intervention. Five studies involved low-calorie/low-fat diets (LCD) – three (Harvey, et al., 1993; C. K. Martin, et al., 2006;

C.K. Martin, Rosenbaum, et al., 2011) with prescribed calorie ranges of between 1000 and 1800 kcal/day, one (Greenway, et al., 2010) based on an individualised energy deficit of approximately 500 kcal/day, and one (Lappalainen, et al., 1990) not stated. Two groups were assigned to VLCD interventions, both based predominantly on liquid supplements. Calorie allowances were 400–500 kcal/day in one (Harvey, et al., 1993), and 800 kcal/day in the other (C. K. Martin, et al., 2006). Two studies (Fabbricatore, Imperatori, Morgia, et al., 2011; Fabbricatore, Imperatori, Pecchioli, et al., 2011) combined patients assigned to both LCDs and VLCDs. Another data set (Gilhooly, et al., 2007) combined patients assigned to both high-glycaemic load (GL) and low-GL diets and with either a 10% or 30% energy deficit. Another study group (C.K. Martin, Rosenbaum, et al., 2011) received a low-carbohydrate diet (LCaD), and were allowed <20 g/day of carbohydrates but unlimited fat and proteins. Although this intervention did not involve calorie restriction per se, carbohydrate-restricted diets are effective at inducing weight loss even without caloric restriction (Hession, Rolland, Kulkarni, Wise, & Broom, 2009), and this is a popular method of weight-loss dieting; consequently, it was decided to include this study in the review. Finally, one group of patients (Lappalainen, et al., 1990) underwent nutritionally supported fasting, with approximately 3 weeks on 200 kcal/day. Only the CALERIE trial reported in Gilhooly et al (2007) used an objective assessment of dietary compliance (Das et al., 2007; Gilhooly, et al., 2007). In this study, adherence was assessed using doubly-labelled water, and in the 30% energy restriction group, actual calorie restriction for participants following the high-GL diet was 21.1% at 3 months and 15.7% at 6 months; in the low-GL group, actual caloric restriction was 27.5% at 3 months and

17.5% at 6 months, indicating a reduction in dietary compliance over time (Das, et al., 2007).

Outcome measures

The included studies assessed various components of food cravings, including frequency, intensity, difficulty resisting the craving, anticipated difficulty in controlling eating if the craved food were consumed, anticipated change in affect if the craved food were eaten, and feelings on actual consumption. Not all questionnaires used assessed all of these factors, and some also incorporated questions about hunger or mood. Most, but not all, included a definition of the term 'craving', usually incorporating the concepts of high intensity and specificity. Of the seven different cravings questionnaires used, only two (the FCQ-T and the FCI) have been psychometrically validated (Cepeda-Benito, et al., 2000; M. A. White, et al., 2002), and both measures have additionally been validated in an overweight and obese population (Vander Wal, Johnston, & Dhurandhar, 2007; Marney A. White & Grilo, 2005). Four studies used validated instruments, four used non-validated instruments – although three of these were published prior to the availability of validated food craving questionnaires, and one used both. Brief details of the questionnaires used in each study are presented in Table 2, and full versions are available in Appendix 4. Of note, both of the validated questionnaires and the study-specific questionnaire developed by Harvey et al. (1993) measured craving frequency using Likert scales. Despite the results representing only ordinal data, all studies using these scales reported their results as mean values and standard deviations from the mean, rather than the median and interquartile range, or other suitable measure of central tendency. Whilst this statistical handling of

ordinal data was used in the original validation studies for the FCI and FCQ-T, and is widespread in the psychological and behavioural sciences, the impact on the meaningfulness of subsequent results is uncertain, particularly in a clinical population where the frequency of cravings data may not be normally distributed.

Two studies provided cross-sectional data only (Fabbricatore, Imperatori, Morgia, et al., 2011; Fabbricatore, Imperatori, Pecchioli, et al., 2011). The remaining six studies reported data on changes in cravings over time for dietary intervention periods of between 3 weeks and 2 years. Three studies (Gilhooly, et al., 2007; Greenway, et al., 2010; Lappalainen, et al., 1990) provided only baseline and final data, and three reported results from intermediate time points (Harvey, et al., 1993; C. K. Martin, et al., 2006; C.K. Martin, Rosenbaum, et al., 2011).

Outcome analysis was conducted on a per-protocol basis in four (Gilhooly, et al., 2007; Harvey, et al., 1993; Lappalainen, et al., 1990; C. K. Martin, et al., 2006) of the six longitudinal studies. Non-completers accounted for between 6% and 41% of the individual study populations. The two larger, longer studies, imputed missing values in participants with at least one baseline and one post-baseline measurement, and both provided usable data on 88% of their randomised participants.

Table 2. Measures of food cravings used in included studies

Study ID	Instrument used	Outcomes measured
Fabbricatore 2011a, 2011b	FCQ-T*[a]	Validated 39-item questionnaire mapping on to nine separate factors: intention to eat craved foods, anticipation of positive reinforcement, anticipation of relief from negative states, possible lack of control if food eaten, thoughts or preoccupations with food, physiological response/hunger, emotions prior to or during cravings/eating, environmental triggers, and guilt resulting from cravings or consumption. Asks how frequently each item would be true, in general? Scored on a 6-point Likert scale (never/not applicable, rarely, sometimes, often, usually, always). 'Craving' not specifically defined.

Table 2. Measures of food cravings used in included studies /cont.

Study ID	Instrument used	Outcomes measured
Gilhooly 2007	(i) Craving Questionnaire[b] (ii) Food Craving Record[c]	(i) Time period is previous 3 months; cravings, defined as "an intense desire to eat a specific food"; types and frequency of foods craved; description of most strongly craved food; possible substitution if craved food not available; frequency of actual consumption; feelings on consumption of the craved food; and relationship to menstrual cycle in women.
		(ii) A series of 100 mm visual analogue scales (VAS) using the phrase "a strong urge to eat particular types of foods"; two scales related to frequency, three to intensity, and one to perception of the term 'craving'.

Table 2. Measures of food cravings used in included studies /cont.

Study ID	Instrument used	Outcomes measured
Greenway 2010	FCI*[d], COEQ[e]	(i) Validated scale assessing frequency of cravings for 28 specific foods, grouped into four categories (high fats, sweets, carbohydrates/starches, fast-food fats) over previous month, with craving defined as "an intense desire to consume a particular food". Each item rated on a 5-point Likert Scale, with (not at all, rarely, sometimes, often, always/almost every day). (ii) 21-item questionnaire comprising a series of visual analogue scales assessing hunger, fullness, desire to eat different foods, mood and alertness, food cravings. Items 9 to 21 refer specifically to cravings, and including six food-specific questions relating to particular foods or types of foods (chocolate; other sweet foods; fruit /fruit juice; dairy; starches; non-sweet 'tasty foods'.

Table 2. Measures of food cravings used in included studies /cont.

Study ID	Instrument used	Outcomes measured
		e.g. burgers, pizza), and ability to resist urges to eat. Food craving is defined as "a strong urge to eat a particular food or drink". Questions relate to previous 7 days.
Harvey 1993	Study-specific questionnaire developed by the authors	Subjects asked to rate their "cravings or desires" for 40 specific foods, grouped into five categories (low-fat protein; high-fat protein; complex carbohydrates; other fats; miscellaneous foods). "At times we all have cravings or desires to eat particular foods. During the past week, to what degree have you wanted to eat the following foods?" Each item rated on a 5-point Likert scale (not at all, a little, somewhat, pretty much, very much).

Table 2. Measures of food cravings used in included studies /cont.

Study ID	Instrument used	Outcomes measured
Lappalainen 1990	Study-specific questionnaire developed by the authors	Patients recorded frequency and intensity of hunger, cravings, and a 'combination feeling'. Craving defined as a "desire to consume a specific food item or drink not related to a deficit of energy, and connected with a different kind of feeling than when hungry". It was further defined as being "associated with seeking for something pleasant, e.g. a pleasant mood".
Martin 2006	FCI*[d]	As above
Martin 2011	FCI*[d]	As above

*Studies marked with an asterisk have been psychometrically validated.

Abbreviations: COEQ, Control of Eating Questionnaire; FCI, Food Craving Inventory; FCQ-T, Food Cravings Questionnaire – Trait.

References: [a]Cepeda-Benito et al, 2000; [b]Weingarten & Elston 1991; [c]Hill et al, 1991; [d]White et al, 2002; [e]Wilcox et al, 2010.

Risk of bias in included studies

The methodological quality of included studies is described in detail in Appendix 2 and an overview is presented in Table 3. Briefly, the two more recent, larger RCTs (Greenway, et al., 2010; C.K. Martin, Rosenbaum, et al., 2011) were both well conducted, with generally low risk of bias. The main concern in the COR-I study (Greenway, et al., 2010) is the uncertain impact of the method used for handling missing data. Approximately 50% drop out was reported in all groups, which is not unusual in weight loss studies, and missing values were imputed using last observation carried forward. Whilst this method can be considered conservative in assessing the value of a weight management intervention, it may result in an underestimation of increased cravings that resulted in drop outs during the relatively long two-month gaps between measurements in the first half of the study, and the six-month gap in the second half.

Amongst the other, smaller, randomised and non-randomised studies, risk of bias was generally low. Although blinding of participants to diet intervention would be difficult in most cases, cravings outcomes are unlikely to be sensitive to this factor, at least among participants. No evidence of selective reporting was apparent in any of the studies, but several studies (Harvey, et al., 1993; C. K. Martin, et al., 2006), or subsets of studies (Lappalainen, et al., 1990), were exposed to potentially important attrition bias, limiting the conclusions that can be drawn from their findings.

Table 3. Summary of risk of bias in included studies

Randomised controlled trials	Gilhooly 2007	Greenway 2010	Harvey 1993	Martin 2011
Random sequence generation (selection bias)	–	+	?	+
Allocation concealment (selection bias)	?	+	?	?
Blinding of participants / personnel (performance bias)	?	+	?	+
Blinding of outcome assessment (detection bias)	+	+	N/A	?
Incomplete outcome data (attrition bias)	+	?	–	+
Selective reporting (reporting bias)	+	+	+	+
Other potential sources of bias	N/A	N/A	?	N/A
Non-randomised studies	Fabbricatore 2011a	Fabbricatore 2011b	Lappalainen 1990	Martin 2006
Comparability of groups at baseline (selection bias)	?	?	N/A	?/+
Allocation (selection bias)	?	?	–	+
Blinding of participants / personnel (performance bias)	+	+	?	?
Blinding of outcome assessment (detection bias)	N/A	N/A	?	?
Incomplete outcome data (attrition bias)	N/A	N/A	+/–	–
Selective reporting (reporting bias)	+	+	+	+
Other potential sources of bias	N/A	N/A	?	N/A

Key: + , low risk of bias; – , high risk of bias; ? , unclear risk of bias; x/x , bias differs between intervention arms; N/A, not applicable.

Effects of interventions

Given the paucity of relevant data, and the wide heterogeneity between studies in terms of study design, participants, interventions, and measured outcomes, meta-analysis was considered neither possible nor appropriate. A narrative analysis of the evidence is presented here, with results presented by outcome measure used.

Validated measures

FCQ-T

Two studies from the same research group utilised the FCQ-T scale, which measures general trait experience of a range of factors relating to hunger and craving. Scoring on each of the 39-items on the FCQ ranged from 0 (never) to 5 (always), giving a possible range of 0 to 195 (Table 2, Appendix 4).

The first study recruited 55 clinical participants (mean BMI 30.1 kg/m^2) attending two specialist weight management clinics (Fabbricatore, Imperatori, Pecchioli, et al., 2011). Of these, 27 were currently receiving treatment at one of the clinics, but had been dieting for four weeks or less, and 28 had not yet begun treatment and were not currently dieting. This clinical sample scored significantly higher on all nine dimensions of the FCQ-T (M = 116.8, SD = 34.2) than did 61 normal-weight (mean BMI 22.2 kg/m^2), non-clinical controls (M = 81.7, SD = 20.8; $p < 0.001$). Within the clinical population, no significant differences in mean total FCQ-T scores were observed between the 27 current

dieters (M = 118.5, SD = 33.6) and 28 not currently dieting (M = 115.2, SD = 35.2; p = 0.72).

In the second study, 102 clinical participants (mean BMI 32.8 kg/m^2) were classed as being either intense (58%) or mild (42%) cravers (Fabbricatore, Imperatori, Morgia, et al., 2011). Intense cravers were defined as those with scores of 103 or above on the FCQ-T. This cut-off was determined by calculating one standard deviation above the mean FCQ-T score of the 61 normal-weight non-clinical controls in the previous study. Scores on the FCQ-T scale were not reported separately for dieters and non-dieters; however, 79.7% of intense cravers were currently dieting compared with 46.5% of mild cravers (p = 0.08). Non-dieters were equally likely to be intense (22/45) or mild (23/45) cravers, but dieters were significantly more likely to be intense cravers (37/57) than mild cravers (20/57)[1]. BMI did not differ between the two groups (32.0 versus 33.8 kg/m^2 in intense and mild cravers, respectively, p = 0.13). Amongst obese patients (n not reported), those classified as intense cravers were more likely to have undergone five or more previous weight loss attempts than mild cravers (81.6% versus 46.5%, $p < 0.05$), and reported higher scores (19.9 vs 7.6, $p <$ 0.001), and clinically significant scores (≥ 18) on the Binge Eating Scale (59.3% versus 7.0%, respectively). No differences were observed between the groups on the BIS/BAS scale (Carver 1994), which assesses measures of reward seeking and avoidance of negative outcomes.

[1]Based on reported values, differences in likelihood of reporting intense or mild craving intensity among dieters calculated using Pearson Chi-Squared Test: χ^2 = (1, N = 57) = 5.07, p = 0.0243.

FCI

Three studies (Greenway 2010, Martin 2006, Martin 2011) assessed cravings using the FCI, which assesses the frequency of "an intense desire to consume a particular food" for 28 specific foods over the previous month. Each items is rated on a 5-point Likert Scale, with 1=not at all to 5=always/almost every day (Table 2, Appendix 4).

In the first study by Martin et al. (2006), only 19 of 39 participants opting to follow a LCD completed the 12-week trial. The completers reported very little change in frequency of "an intense desire to consume a particular food" for any of the four included food groups, with only small decreases being seen in cravings for sweets, carbohydrates and starches, fast food fats, or for cravings in general over the intervention period, and none reached statistical significance. Almost no change was observed in the high-fat food group. Although no significant pattern of change was observed in this study, these data are based on only 19 subjects, and it is likely that the study was underpowered to detect significant change in craving measures as this was not a primary outcome of the parent study. In contrast, significant changes were observed in the participants in the VLCD group who provided readings at 12 weeks (n=39), with reports of significant decreases in cravings for all food types between baseline and Week 6 (all $p < 0.00001$); these lower levels were maintained at Week 12 and after a 6-week re-feeding phase (n=22). Again, a significant number of the original 59 participants in the VLCD group withdrew before study completion. Whilst they did not differ significantly from completers on baseline measures, the

possibility that at least some dropped out due to increased cravings during dieting cannot be excluded.

In the second study from this research group (C.K. Martin, Rosenbaum, et al., 2011), 307 participants were randomised to either a low-fat diet (LFD) or a low-carbohydrate diet (LCaD). Cravings data were collected at baseline, and at 3, 6, 12, 18 and 24 months. A conservative modified intent-to-treat analysis was applied, including any participant with measurement data at baseline plus at least one other time point, with missing data accounted for using a likelihood-based method. Of the 307 randomised participants, data were available at two or more time points for 270 (88%) subjects. The LFD intervention, which was similar to the LCD intervention in the previous study, included 134 subjects with usable data. The low-fat diet participants showed similar patterns of change in cravings for all four food groups, namely small decreases in the early part of the intervention, consistent with the findings in the earlier study. The decreases at 3 months were significant only for sweet cravings and fast-food fats. No statistically significant changes were observed in the frequency of cravings for high-fat foods in general or for carbohydrate/starchy foods (Appendix 5, figure A1). All measures returned towards baseline levels over subsequent time points to 18 months, but then decreased again in the final 6-month period. This pattern may represent dietary fatigue and reduced adherence over the course of the long study, with a final push at improving compliance as the study neared its end. The smallest changes were observed in carbohydrate cravings, which remained similar to baseline levels throughout.

Among the 136 participants randomised to the LCaD for whom data were available at two or more time points, cravings for sweets, carbohydrates and fast-food fats decreased to a small extent over the first three months, with continued minor decreases up to 6 months. As with the low-fat diet group, only the changes in cravings for sweets and fast-food fats were significant at 3 months, although cravings for starchy foods approached statistical significance (mean difference -0.14, 95% confidence interval 0.00 to 0.28) (Appendix 5, figure A1). Most scores then increased steadily towards baseline levels for the remainder of the intervention period. The reductions were larger than in the LFD group at most time points, in particular, larger reductions were observed in carbohydrate/starch cravings in the LCaD group. In contrast, cravings for high-fat foods among low-carbohydrate dieters increased above baseline levels in the first six months of the study, and then remained steady for the remainder of the intervention period. With the exception of cravings for fats in the LCaD group, all scores remained below baseline at 24 months. In general, changes in cravings were correlated with changes in weight. Rebound of cravings scores in the latter part of the intervention may be correlated with diet 'fatigue' and be associated with reduced compliance; consistent with this, weight loss peaked at 6 months in both groups, then gradually rose again, remaining about 7% below baseline at the end of the study.

The third study to use the FCI was the COR-I trial, a large placebo-controlled RCT evaluating the effects of Contrave (bupropion plus nalterxone) for weight loss (Greenway, et al., 2010). Changes in FCI total and subscale scores were not

reported – only that no differences were observed between placebo and drug interventions.

Other outcome measures

Craving Questionnaire and Food Craving Record

One study (Gilhooly, et al., 2007), the CALERIE trial, used the Craving Questionnaire developed by Weingarten and Elston (1991), and the Food Craving Record developed by Hill et al. (1991) (see Table 2 and Appendix 4). The trial involved randomisation to either a high-GL or a low-GL diet, and to either 30% or 10% calorie restriction. The female subset of participants in the parent trial (n=32) completed cravings questionnaires at baseline and 6 months. No difference was seen in either weight loss or cravings between the randomised groups and consequently, data were presented for the group as a whole.

Cravings, defined as "an intense desire to eat a specific food", were common in the sample. At baseline, 29/32 women had experienced a craving in the previous 3 months, and at the 6-month mark the number was 30/32. At six months, no significant difference was reported in frequency of the strongest craving (times/month), craving frequency score (VAS), craving intensity score (VAS), or mean portion size of craved food if eaten, compared with baseline. The largest difference was noted in the frequency of follow-through on cravings, which reduced from 64% to 27% of the time ($p < 0.001$). The nutritional characteristics of the types of foods craved also did not differ significantly over the study period. At both time points, chocolate was the most commonly craved food, followed by salty snacks.

This study also found a strong correlation between cravings and hunger. 'Hunger-susceptibility' score on the Eating Inventory were related to various craving parameters at both baseline and 6 months. Whilst not significant at baseline, craving strength and per cent follow-through were strongly correlated with hunger scores at 6 months (r = 0.44 and 0.45, respectively; both p = 0.01). In contrast, no statistically significant associations were found between any cravings measure and dietary restraint at either time point. Greater weight loss during the 6-month period was associated with increased cravings for higher energy density foods, but with decreased follow-through.

COEQ

In addition to the FCI, the COR-I trial (Greenway, et al., 2010) also used the COEQ as an outcome measure. This tool assesses hunger, mood, and cravings, and scores within the placebo group are reported at baseline, Week 8 and Week 56. Using 100 mm VAS measures, small decreases were observed in the frequency (15%), intensity (16%), and difficulty resisting (13%) food cravings at Week 8, although the change in overall frequency did not reach statistical significance (Appendix 5, figure A2). Consistent with this, respondents also reported an approximately 20% reduced follow-through of cravings and a 22% reduction in their perceived difficulty in controlling their eating generally, both statistically significant. Frequency of cravings for sweet foods, starchy foods, and fast-food 'tasty foods' were the most reduced, with only minor differences in the frequency of cravings for dairy products and fruit. Hunger levels decreased by a similar amount, but few changes were noted for sensations of fullness, mood, or

alertness. Overall, these decreases were maintained at Week 56, although some slight rebound was noted in most measures. Only anxiety was increased (approximately 14%) above baseline at Week 56. Given that Contrave comprises two compounds used in the treatment of addictive-type disorders, the size of any placebo effect on cravings cannot be determined, and indeed, the placebo group differed from the drug groups on remarkably few measures. However, the results are largely consistent with the cravings literature as a whole.

Study-specific questionnaires

Lappalainen et al. (1990) conducted a small 4-week study (one week baseline, three weeks intervention), in which 18 obese treatment-seeking patients were allocated to either dieting (individualised calorie deficit) or fasting (200 kcal/day) interventions based on personal preference. Patients were instructed to record their experiences of hunger, cravings, and combined hunger/cravings on a record sheet, as soon as possible after experiencing the sensation. Intensity of the sensation was to be recorded on a 100 mm VAS, anchored at 10 mm intervals from 'none' to 'maximal'. Patients in the fasting group were also asked to record the antecedents, coping strategies and duration of each experience.

Of the eight patients opting for the diet intervention, two withdrew and analysis was performed on data from the remaining six participants. Small reductions (0.47 times/day) were reported in craving frequency by the diet group over the course of the intervention. Hunger also reduced by a small amount (0.18 times/day). As baseline data were not reported for these variables, it was

not possible to estimate the relative size of this change. No significant difference in hunger response to visual food cues was observed.

In the fasting group, craving frequency decreased by 0.75 times/day and hunger by 0.98 times/day. As above, absence of baseline data precluded estimation of the relative size of this effect. Hunger response to visual food cues was significantly reduced from baseline in this group.

A mean daily frequency score was calculated from the measures of hunger, cravings, and hunger+cravings. This score was largely unchanged in the dieting group over the course of the intervention, but decreased in the fasting group. These differences were not statistically significant, but given the very small sample size, the study was probably underpowered to detect significant differences between the groups. The authors noted that while frequency appeared to decrease more in the fasting group, the more demanding reporting requirement for this group might have affected compliance with recording, resulting in an inflated effect size. Nevertheless, these findings are consistent with the bulk of the literature.

Harvey et al. (1993) asked 93 participants undergoing either a LCD or a VLCD to rate their "cravings or desires" for 40 different foods over the previous week, with the phrasing: "to what degree have you wanted to eat the following foods". This particular phrasing is open to interpretation in terms of frequency and/or intensity. Questionnaires were completed bi-weekly for the first 19 weeks of the intervention, but results are reported for four time periods – baseline (Week 1),

VLCD1 (Weeks 3, 5, and 7), VLCD2 (Weeks 9, 11, and 13), and Refeeding (Weeks 15, 17, and 19). These time periods correspond to the first half, second half, and the refeeding phase of the VLCD intervention; the LCD group followed the same diet throughout. Responses were given on a 5-point Likert scale (1 = not at all; 2 = a little; 3 = somewhat; 4 = pretty much; 5 = very much). Overall, baseline craving scores were low. In the LCD group, only 11 of 40 items scored at least '3.0', the majority being in the 'complex carbohydrates' group (cereal, spaghetti, raw vegetables, other cooked carbohydrates, and raw fruit. Three were categorised as 'other fats' (cakes/donuts/cookies, ice cream, and butter/margarine), one as high-fat protein (cheese), and two as miscellaneous (fruit juice, salty snacks/pretzels). The only item to score above 3.5 was 'raw fruit' (3.8). Chocolate scored 2.9. Only very small reductions in craving scores were observed in this group over the VLCD1 time period. Only the changes in desire for high-fat proteins and 'other fats' were statistically significant (Appendix 5, figure A3).

In the VLCD group, baseline scores were generally a little higher than in the LCD group, with 15 of 40 items being given a score of 3.0 or greater. These high-scoring items were also spread more evenly over each of the five food types. Two items were classified as low-fat protein (roast chicken, tuna fish), two as high-fat protein (fried chicken, cheese), five as complex carbohydrates/starches (bread, spaghetti, other cooked carbohydrates, baked potato, raw fruit), four as other fats (cakes/donuts/cookes, chocolate, ice-cream, butter/margarine) and two as miscellaneous (fruit juice, salty snacks/pretzels). Again, raw fruit was the highest scoring item (4.0). Given that assignment to the diet groups was

randomised, these differences are likely due to chance alone. Moderate decreases in cravings were seen in virtually all food items over the course of the VLCD intervention and all were statistically significant (Appendix 5, figure A3). These decreases were maintained during the VLCD2 time period and during the 6-week refeeding phase. Weight loss was not correlated with change in craving scores. However, non-completers (14% of randomised sample) were significantly younger and heavier at baseline that those who completed the study. It is possible that these subjects struggled more with cravings and had poorer weight loss outcomes. Analysis of data from non-completers and continuers at time of dropout may have been informative. However, this rate of dropout is fairly low for a weight loss study, and is unlikely to have had a large impact on overall findings.

Summary of Findings

A summary of the key findings is presented in Table 4. Overall, low-calorie dieting appeared to have little or no effect on frequency, intensity, or type of cravings. In contrast, severe caloric restriction appears to reduce the frequency of cravings in general as well as the frequency of intense cravings. Low-carbohydrate diets appear to reduce the frequency of carbohydrate cravings and increase cravings for high-fat foods. In the short-term, reduction in cravings do not appear to correlate with weight loss; however, findings from the one, larger, long-term intervention study (C.K. Martin, Rosenbaum, et al., 2011) suggest that frequency of intense cravings do decrease with increasing weight loss, and rebound with weight gain.

Table 4. Summary of key findings

Study ID	Cravings data	Duration	N	Frequency (general)	Frequency (intense)	Intensity	Food type	Correlation with weight loss
Fabbricatore 2011a	XS	NA	57 D/45 ND	NR	NM	NM	NM	NA
Fabbricatore 2011b	XS	NA	27 D/ 28 ND	No difference D vs ND	NM	NM	NM	NA
Gilhooly 2007	CS	6 mths	32	NM	No significant change	No significant change	Small ↑ bread/ pasta, pizza; small ↓ in chocolate, ice cream	NR, but ↑ weight loss associated with ↑ cravings for energy-dense foods
Greenway 2010	CS	56 wks	511	NM	Small ↓	Small ↓	NR (small decrease starchy foods, fats, and sweets)	NR
Harvey 1993	CS	19 wks	LCD: 42	Little/no effect	NM	NM	Most small ↓, moderate ↓ in fatty foods	No
			VLCD: 38	Moderate ↓			All ↓	
Lappalainen 1990	CS	3 wks	LCD: 6	Small ↓	NM	NR	NM	NR
			Fasting: 7	Moderate ↓				
Martin 2006	CS	12 wks	LCD: 19	NM	No significant change	NM	All small ↓	No
			VLCD: 39		Significant ↓		All ↓	
Martin 2011	CS	2 yrs	LFD: 136	NM	Initial ↓, gradual ↑ in longer-term	NM	All ↓	Yes
			LCaD: 134		Initial ↓, gradual ↑ in longer-term		Fat ↑, carbs ↓↓	

Abbreviations: CS, case series (uncontrolled pre/post); D, diet group; LCD, low-calorie diet; LCaD, Low-carbohydrate diet; LFD, low-fat diet; NA, not applicable; ND, non-diet group; NM, not measured; NR, not reported; VLCD, very-low-calorie diet; XS, Cross sectional.

Discussion

Perhaps one of the key findings of this systematic review is that despite increasing interest in the field of food cravings within the context of increasing the efficacy of weight-loss interventions, searches did not identify a single study comparing the longitudinal effect of dieting versus non-dieting on the frequency, intensity, or subjective experience of cravings in an exclusively overweight population.

Low-calorie dieting appeared to have little or no effect on the frequency of food cravings in general. However, this finding is based on a sample size of only 75 dieting subjects. In the one cross-sectional study that rated the frequency of cravings in dieting versus not dieting subjects (Fabbricatore, Imperatori, Morgia, et al., 2011), no difference was found between 27 dieting and 28 non-dieting subjects, despite the fact that both LCD and VLCD participants were grouped together in the dieting analysis. However, this is not entirely surprising given that the measure used was the FCQ-T, which assesses trait cravings. As the dieting and non-dieting populations were clinically similar, and the dieters had been on their regimens for less than four weeks, it would seem unlikely that large differences would be observed between these groups. Consistent with the FCQ-T being better designed to differentiate between clinical and non-clinical populations, within the overweight and obese sample, both the dieters and non-dieters scored significantly higher on all measures of the FCQ-T than did 61 normal weight, community controls, and over 40% higher on the total score. It is possible that the FCQ-S, which measures state cravings, might be more

sensitive to the effects of current dieting on cravings within a clinical sample, whereas the FCQ-T may be a better reflection of dieting history and/or current overweight status.

Moderate reductions in craving frequency were observed with severe calorie restriction, but again sample sizes were small – 38 participants in a VLCD group and seven in a fasting intervention. The authors of the fasting study noted that the heavier reporting burden required of the fasters versus the low-calorie dieters may have resulted in lower compliance with study protocol and reduced recording of actual instances of cravings (Lappalainen, et al., 1990). This study also asked for information about the intensity of cravings, but did not report these results due to a large number of missing values. This is unfortunate, as intensity would be unlikely to be sensitive to under-reporting and may have corroborated the apparent effect of fasting on food cravings. Additionally, this study was of short duration – one week baseline and three weeks intervention. The availability of early data points might have provided useful information regarding very early changes in cravings following instigation of calorie restriction. However, both the definition of the terms used and the manner in which the findings were reported precluded a detailed analysis.

Specifying an intensity component in questions about the frequency of cravings, as was done in four of the studies (Gilhooly, et al., 2007; Greenway, et al., 2010; C. K. Martin, et al., 2006; C.K. Martin, Rosenbaum, et al., 2011), did not appear to increase the impact of dieting on the incidence of food cravings. The two smaller studies (Gilhooly, et al., 2007; C. K. Martin, et al., 2006), comprising 51 low-

calorie dieters between them, found no effect of dieting on the occurrence of intense specific food desires. In contrast, however, the larger studies (Greenway, et al., 2010; C.K. Martin, Rosenbaum, et al., 2011), with a total of 647 subjects following low-calorie diets, both recorded small but significant decreases in reported food cravings. These studies were also longer than the other included studies – 56 weeks and 2 years, respectively – the implications of which will be discussed further below. Again, larger decreases were observed in the 39 subjects undergoing more severe calorie restriction (C. K. Martin, et al., 2006).

The questionnaire used by Harvey et al. (1993), specified neither frequency nor intensity, but rather asked "to what degree" individuals "wanted to eat" 40 specific foods; responses were given on a Likert scale composed of vague colloquial phrases that again failed to clarify the construct of interest. Given the ambiguity in the question, and the lack of a specific definition of the phrase 'craving', interpretation of the findings is difficult. As noted above, baseline values for most of the items were similar and not particularly high; further, a number of methodological variables may have inflated even these values, including the lack of an intensity requirement (Gendall, et al., 1997) and the potential conflation of 'craving' with 'desire' in the original question. Very little change was observed in desire for any of the items over the course of the study in low-calorie dieters, although greater decreases were seen in subjects in the VLCD arm. However, use of mean values and standard deviations to describe ordinal data may have diluted the impact of any strong cravers. As with all of these studies, use of, for example, the median and interquartile range, may have been more informative.

Thus, energy restriction appears to have little effect on craving frequency, however it is defined, unless the restriction is extreme, or of longer duration. This observation must be tempered, however, by the fact that the majority of studies reported per protocol analyses only. The possibility that some subjects experienced significant increases in cravings, which resulted in their non-completion of the respective studies, cannot be ruled out.

Only two studies specifically measured changes in craving intensity over time. The smaller of the two (Gilhooly, et al., 2007) reported no significant change from baseline after six months of either low-GL or high-GL dieting, but comprised only 32 subjects. The larger study (Greenway, et al., 2010) recorded a 16% decrease in craving intensity after eight weeks in over 500 subjects, maintained after one year. However, these subjects were receiving a placebo in a trial of a drug with a potential effect on cravings, and the effect of patient expectations cannot be accurately estimated. Given the possible effect on reducing cravings of the experimental drug, the placebo effect may account for the similarity in cravings scores between recipients of the placebo and those receiving the trial drug. An alternative explanation is that the drug did not significantly reduce food cravings in the experimental group, and the 16% decrease in craving intensity, almost identical to the effect size in reduction of frequency of intense cravings, may be due to diet alone. However, caution must be applied in interpreting these results as nearly 300 participants dropped out before the end of the study, 70 of them prior to Week 8, and missing values were imputed using the method of last observation carried forward. This method provides conservative estimates of weight loss, but may underestimate potential

increases in cravings that resulted in withdrawal of non-completers. Thus, even given the large sample size and the high methodological quality of the study, it would be unwise to draw any definite conclusion from these findings.

A different approach to evaluating craving intensity was taken by Fabbricatore et al. (2011). Using the FCQ-T in a cross-sectional design, 102 overweight and obese individuals were categorised as either intense or mild cravers, based on a cut-off derived from community norms. Interestingly, whilst the authors found no difference in BMI or psychological measures of reward seeking and disinhibition between current dieters and non-dieters, current dieters were significantly more likely to be classified as intense cravers than as mild cravers. No difference was observed in the group who were not currently restricting their energy intake, suggesting that dieting does increase craving intensity.

The effect of dieting on cravings for specific types of foods is less likely to be sensitive to the methodological issues described above, and was reported in five of the included studies (Gilhooly, et al., 2007; Greenway, et al., 2010; Harvey, et al., 1993; C. K. Martin, et al., 2006; C.K. Martin, Rosenbaum, et al., 2011). Across all five studies, reduced-calorie/low-fat dieting, of the kind most often prescribed in clinical weight loss interventions, tended to result in small reductions in cravings for the kinds of foods that are typically reported as being particularly 'addictive' in overweight and obese populations – namely, carbohydrates and starches, sweets, and energy-dense fatty foods; these are also the foods for which consumption is likely to be reduced during standard reduced-calorie diets. In diet interventions where specific foods were restricted,

in particular the low-carbohydrate diet, cravings for carbohydrates were greatly reduced. In contrast, cravings for fats, which were freely allowed on this diet, were increased. This finding belies the 'forbidden fruit' hypothesis, which suggests that a sense of psychological deprivation drives a desire to consume the restricted food (Polivy, et al., 2005).

These results are not readily reconcilable with the findings of a recent study by Massey & Hill (2012), who reported that 52 overweight current dieters experienced significantly stronger, harder to resist, cravings for foods they were trying to restrict, than did 40 'watchers' - a normal weight population who 'watch what they eat' in order not to gain weight, and both groups had stronger cravings for restricted foods than did normal-weight non-dieters. The sample in the study by Martin et al. was much heavier than that in the study from Massey & Hill (mean BMI 36.0 versus 29.1 kg/m^2, respectively). In addition, the settings were quite different, with the former study being an RCT in an academic setting, and the latter involving a sample of community weight-loss group attendees. However, these differences might be expected to result in more intransigent craving experiences and disordered eating behaviours in the trial population than in the community sample – the opposite of what was observed. Thus, the reasons for the discrepancies are not clear.

The findings in Gilhooly et al. (2007), which compared a low-GL with a high-GL diet, are also difficult to interpret. The nutritional composition of the most strongly craved food did change between baseline and six months for some food types, with cravings for chocolate being the most reduced in frequency. In

contrast, cravings for bread, pasta, and pizza all increased. Unfortunately, the data are combined for those on the high- and low-GL diets, and it is difficult to gauge whether the low-GL dieters were driving the increase due to cravings for high-glycaemic-load carbohydrates. It is also worth noting that only the results for the strongest craved food are presented, and these figures represent only a small portion (all < 10 subjects) of an already small sample size. Larger studies are required to identify whether reduced glycaemic load differentially increases or decreases cravings for carbohydrates.

An alternative to the deprivation hypothesis of food cravings aetiology has been suggested. The apparent reduction in strong desire for restricted foods, and increase in desire for allowed foods, is consistent with a conditioning model of food cravings (C.K. Martin, McClernon, Chellino, & Correa, 2011). This model suggests that food cravings are a learned behaviour, deriving from repeated pairing of certain foods with situational cues (e.g. location, dysphoria), or simply with hunger. This model is consistent with different types of foods being craved in different cultures (Komatsu, 2008; Parker, et al., 2003). Laboratory-based studies have also provided empirical evidence in support of this hypothesis. For example, in high chocolate cravers (normal weight undergraduate students) who ate chocolate twice a day when hungry (two hours post-prandially) had an increase in cravings for chocolate when hungry at the end of the test period, but desired chocolate less when full compared with baseline (Gibson & Desmond, 1999). Interestingly, low cravers also experienced an increase in chocolate cravings when hungry after two weeks of pairing chocolate consumption with hunger state, as well as in the fed state. In contrast, both cravers and non-cravers

who consumed chocolate twice a day when full experienced significant decreases after two weeks in both the hungry and fed states. Thus, cravings can be induced in low cravers by pairing consumption with hunger states, and reduced in high cravers by pairing consumption with fed states. This model could explain why cravings appear to decrease in successful (short-term) weight loss, as the apparent compliance with caloric restriction is associated with fewer paired responses of desired foods in response to hunger. The conditioning model gains further support from the significant reductions in both frequency and intensity of food cravings observed during very-low-calorie dieting (C. K. Martin, et al., 2006) and fasting (Lappalainen, et al., 1990), both of which are associated with significant decreases in hunger as well as in energy intake. However, whilst much of the evidence appears to link cravings more to hunger than to other physical or psychological factors, care must be taken in the interpretation of this relationship, as several of the included studies used measures that included aspects of both hunger and cravings, or used questions where hunger and cravings could be conflated, so the fact that total cravings scores show a correlation with hunger may simply be an artefact of the experimental method used. Further evidence for this potential confounder comes from the Food Craving Questionnaire. While the Trait version (FCQ-T) is positively but weakly correlated with BMI, the State version (FCQ-S) in unrelated to BMI but positively correlated with time since the last meal (Cepeda-Benito, et al., 2000; Meule, et al., 2012; Vander Wal, et al., 2007).

However, the conditioning model is also consistent with the increased cravings for fats and reduced cravings for carbohydrates observed in subjects undergoing

a low-carbohydrate diet (Martin et al., 2011). In this case, it is possible that adherence to the dietary guidelines results in fewer instances of pairing hunger with carbohydrate foods, and more frequent pairings with high-fat foods, and these findings provide additional support for the conditioned-response hypothesis.

The findings of Gilhooly et al. (2007), by contrast, do not support the conditioning model. In this study, greater weight loss (and therefore presumably greater energy restriction) was associated with increased cravings for energy-dense foods, but significantly reduced follow through. Whilst this was a small study, whose limitations are discussed above, these findings are consistent with those of a recent validation study of a German version of the FCQ. This study found that the FCQ-S could not differentiate between successful and unsuccessful dieters, suggesting that all dieters had similar experience of cravings but success was presumably associated with better coping mechanisms (Meule, et al., 2012). It should be noted however that the sample in this study was a normal-weight undergraduate population, who were generally unlikely to be dieting for the purposes of weight loss, and that dieting 'success' was based on self-perception.

The findings from Gilhooly et al. (2007) notwithstanding, an alternative hypothesis involves the possibility that reductions in cravings are associated with weight loss, rather than energy restriction per se. The findings on this issue are equivocal. Harvey et al. (1993) found no significant association between cravings for specific foods and extent of weight loss. In contrast, the larger, 2-year study conducted by Martin et al. (2011) found that the occurrence of

cravings – defined as an intense desire to consume a specific food – did correlate with weight loss, in both directions. Thus, over the course of the trial, weight loss peaked at six months in both diet groups, with weight gradually rising again over the subsequent 18 months, remaining just below baseline at the end of the study – a pattern that was mirrored by the reported incidence of food cravings, although the direction of causality cannot be determined from these results.

One possible explanation for this phenomenon is that a biochemical alteration resulting from the weight loss itself affects food cravings, and consistent with this, weight-loss maintainers report very high levels of food cravings (Ogden et al., 2012). An obvious candidate for such a role would be the appetite-regulating peptide leptin, one of several adipokines whose blood levels are reduced following loss of fat mass (Rolland, Hession, & Broom, 2011). Leptin acts on the hypothalamus and signals satiety when fat stores are adequate (Rosenbaum, Kissileff, Mayer, Hirsch, & Leibel, 2010); but it has also been shown to act on the mesolimbic dopamine system, possibly providing a link between energy homeostasis and the reward pathways (Grosshans et al., 2012). Thus, relative leptin deficiency (compared with starting weight) may reduce feeding inhibition signals and drive increases in appetite and cravings in order to restore baseline weight (Cornier, 2011). Indeed, in a single-blind, placebo-controlled in-patient weight-loss study, administration of leptin was shown to ameliorate reduced satiation in obese subjects on a liquid supplement diet (Kissileff et al., 2012).

Although the study by Harvey et al. (1993) failed to report any correlation between weight loss and changes in cravings, this was a much smaller study than

that by Martin et al. (2011), and also did not differentiate between frequency and intensity of cravings. Further, as noted above, the description of the variable of interest given to the participants may have been problematic.

An alternative, and not mutually exclusive, explanation for the theorised relationship between weight loss and food cravings, is one where the cravings are mediated by dysphoric mood. Intentional weight loss (IWL) has been found to correlate with decreased negative affect. A recent systematic review identified 31 RCTs that measured depressive symptoms before and after IWL (Fabricatore et al., 2011). Between them, the studies represented nearly 8,000 participants, and meta-analysis found that nearly all non-pharmacologic methods of IWL resulted in significant decreases in depressive symptoms. The extent of weight loss was not significantly correlated with the degree of improvement in symptoms, possibly suggestive of a non-biological mechanism. Further, amongst 'successful weight losers', weight regain followed by recovery is associated with only minor changes in depressive symptoms, whereas failure to recover is associated with a significant increases in depression (Phelan, Hill, Lang, Dibello, & Wing, 2003). Thus, there appears to be a clear relationship between IWL and affect, which could have important implications for the incidence of food cravings among dieters. The inverse relationship between mood and cravings is fairly well established in the literature (A.J. Hill, 2007), and the self-medication hypothesis of carbohydrate cravings in particular is gaining empirical support (Corsica & Spring, 2008). Thus, the findings of Martin et al. (2011), whereby the frequency of intense cravings appeared to track both weight loss and regain, may be explained by changes in mood associated with the weight loss, rather than the

dietary restriction or reduction in adiposity itself. If the self-medication hypothesis of the aetiology of food cravings is correct, at least in a subset of obese individuals, weight loss and improved mood would be expected to produce a concurrent decrease in cravings; conversely, weight regain would be expected to correlate with worsening of mood and the subsequent return of cravings for mood-modulating foods, consistent with what was found in Martin et al. (2011).

The mechanism by which mood is modulated by weight loss in not well understood. However, one possibility is that the negative mood associated with obesity, and improved mood associated with weight loss, are a consequence of societal stigmatisation of obesity. Consistent with this, a recent review of prospective population studies indicated much stronger evidence for obesity as a predisposing factor for depression than for the reverse (Faith et al., 2011).
It has also been demonstrated that populations disproportionately affected by body image concerns (for example younger age, female, or Caucasian populations) experience greater BMI-associated morbidity and mortality, and that actual/ideal-weight dissonance predicts both negative mental and physical wellbeing, even after controlling for actual BMI (Muennig, Jia, Lee, & Lubetkin, 2008). In further support of the stigma hypothesis, suicidal ideation is greater in obese women than obese men, and interestingly related to underweight in men (Klinitzke, Steinig, Bluher, Kersting, & Wagner, 2012) – both suggestive of a possible psychological impact of not matching culturally desirable gender norms for body type. Thus, it would seem reasonable that IWL would lead to reductions in social stress and, consequently, improved mood, particularly in women. The

findings of Martin et al. (2011) were not reported separately by gender, but the sample was two-thirds female. It would be interesting to see whether there were any differences in the weight/cravings relationship according to sex.

Interestingly, the systematic review by Fabricatore et al. (2011) found that non-diet interventions designed to foster increased self-acceptance and mental wellbeing (generally included as control groups versus standard diet interventions) also resulted in significant decreases in depressive symptoms, without causing weight loss. A non-weight based paradigm known as Health At Every Size (HAES)® is increasing in popularity as a means of achieving improved health. HAES focuses on size acceptance, eating intuitively, and increasing physical activity in an enjoyable manner. A review of RCTs that evaluated HAES in comparison with standard weight-loss interventions identified seven such studies (Bacon & Aphramor, 2011). All reported positive impact on psychological wellbeing and markers of metabolic health, on a par with improvements achieved by traditional dieting. However, the health improvements in the HAES subjects were maintained long-term, whereas dietary interventions tended to result in weight cycling, with all initial health improvements lost on weight regain. To date, no RCTs of HAES have examined the construct of food cravings, but it would be interesting to see whether the incidence and severity of food cravings follows the same pattern.

In conclusion, therefore, it would seem that standard weight-loss dieting does not significantly impact on food cravings, at least in the short-term, although there is some suggestion that restrictions on certain food types may result in

decreased cravings for those foods, in support of a conditioning model of cravings. In contrast, although nevertheless consistent with the conditioning model, severe caloric restriction may result in reduced frequency and intensity of cravings for all food groups, most likely associated with the overall reduction in hunger that is reported during this type of intervention.

However, if cravings are predominantly a psychological appetitive drive that is associated with the physiological experience of hunger, then the evolutionary purpose of cravings in the absence of hunger is uncertain. One hypothesis is that specific food cravings (as opposed to a general desire to eat), may serve to address specific nutritional deficits. Although the physiological basis of food cravings is not well supported by the literature (A.J. Hill, 2007; Weingarten & Elston, 1990), there is evidence to suggest that cravings may be driven by the sensory properties of food (Michener & Rozin, 1994; Smit, Gaffan, & Rogers, 2004). Pelchat & Schaeffer (2000) demonstrated that a nutritionally adequate, but monotonous, sweet, liquid diet increased cravings for savoury food stuffs, and hypothesised that the craving for a variety of sensations, in the absence of hunger, may serve an adaptive function in ensuring the nutritional adequacy of the diet as a whole.

Other models of craving aetiology also garner support from the literature, and it is likely that more than one mechanism is involved. However, the data on which these results are based must be interpreted with caution. In most of the studies included in this review, craving measures were not the primary outcomes of interest, and thus, the majority are likely to be underpowered to detect any

significant changes. Difficulties in evaluating the true effect of dieting on food cravings are further compounded by the often subjective interpretation of 'craving', the possible conflation of cravings with hunger, and the sometimes inappropriate statistical methods used to report the findings.

Another methodological issue is that increased study duration (a situation more representative of dieting in overweight and obese populations in naturalistic settings), tends to result in high rates of attrition, and whatever method is used, if any, to handle missing data, it is unlikely to adequately capture cases where increased cravings resulted in programme dropout, particularly in any subjects who are highly sensitive to or intolerant of craving sensations and who may be amongst the earliest to withdraw. As this is the group most likely to benefit from a deeper understanding of craving phenomenology, this problem must be addressed in future cravings research. One suggestion is to make use of modern communication technology, such as smartphones, to capture real-time data in naturalistic settings – a technique known as Ecological Momentary Assessment (C.K. Martin, McClernon, et al., 2011). Thus, even if subjects withdraw from a study prematurely, useful information will have been collected.

This review has a number of limitations. Limited resources meant that only the English-language literature could be searched. Whilst this is a potential source of bias, the construct of 'craving' apparently has limited importance in non-Western, non-English speaking countries, with no equivalent linguistic term existing in a wide range of language (Hormes & Rozin, 2010), and thus, the restriction to English-language publications seems unlikely to have had a large impact. Given

the limited evidence supporting a biological basis for food cravings, and the lack of synonymous constructs in other cultures and languages, it is possible that cravings, as they are understood in Western culture, may be a man-made construct – a socially acceptable post hoc explanation for consumption of 'naughty' foods beyond apparent physiological need. This would be consistent with the lack of such a phenomenon in countries where dieting is not the norm and guilt is not usually associated with consumption of high energy density foods.

Perhaps a greater limitation in the methodology of this review is that the diverse terminology used in the literature to discuss concepts related to cravings may not have been identified by the search terms used. In addition, limitation of search terms to title or title/abstract fields for pragmatic reasons may have resulted in some relevant studies being overlooked. However, while it is probable that not every study of dieting in overweight populations that measured cravings was captured in the searches, it is less likely that any studies whose primary interest was food cravings would have been missed, and examination of reference lists and review articles would have reduced this possibility further. In terms of data synthesis, the wide heterogeneity between studies made aggregation of data inappropriate. In addition, the lack of longitudinal studies comparing dieting with not dieting in an overweight population necessitated a somewhat crude separation of study arms into within-group before-and-after data sets, which reduced the evidential quality of the findings and limited the conclusions that could be drawn from the individual study arms.

Thus, at this time, it would be premature to make recommendations pertaining to weight-loss interventions in a clinical population. Future studies should use clearly defined explanations of the construct of interest. Current weight-loss dieting should be clearly differentiated from ever-dieting, weight-maintenance dieting, and dietary restraint. Finally, more large studies are needed, as are more longer-term studies that reflect the ongoing nature of most weight-loss attempts and changes in patterns of cravings over the naturalistic course of these attempts, and efforts should be made to capture frequency, intensity, and type of craving in a prospective, ideally real-time, manner.

References

Included studies

Fabbricatore 2011a

Fabbricatore, M., Imperatori, C., Morgia, A., Contardi, A., Tamburello, S., Innamorati, M., et al. (2011). Food craving and personality dimensions in overweight and obese patients attending low energy diet therapy. *Obesity and Metabolism-Milan, 7*(1), E28-E34.

Fabbricatore 2011b

Fabbricatore, M., Imperatori, C., Pecchioli, L., Micarelli, T., Contardi, A., Tamburello, S., et al. (2011). Binge eating and BIS/BAS activity in obese patients with intense food craving who attend weight control programs. *Obesity and Metabolism-Milan, 7*(1), E21-E27.

Gilhooly 2007

Gilhooly, C. H., Das, S. K., Golden, J. K., McCrory, M. A., Dallal, G. E., Saltzman, E., et al. (2007). Food cravings and energy regulation: The characteristics of craved foods and their relationship with eating behaviors and weight change during 6 months of dietary energy restriction. *International Journal of Obesity, 31*(12), 1849-1858.

Greenway 2010

Greenway, F. L., Fujioka, K., Plodkowski, R. A., Mudaliar, S., Guttadauria, M., Erickson, J., et al. (2010). Effect of naltrexone plus bupropion on weight loss in overweight and obese adults (COR-I): a multicentre, randomised, double-blind, placebo-controlled, phase 3 trial. *Lancet, 376*(9741), 595-605.

Harvey 1993

Harvey, J., Wing, R. R., & Mullen, M. (1993). Effects on food cravings of a very low calorie diet or a balanced, low calorie diet. *Appetite, 21*(2), 105-115.

Lappalainen 1990

Lappalainen, R., Sjoden, P. O., Hursti, T., & Vesa, V. (1990). Hunger/craving responses and reactivity to food stimuli during fasting and dieting. *International Journal of Obesity, 14*(8), 679-688.

Martin 2006

Martin, C. K., & O'Neil, P. M. (2004). Changes in food cravings during dieting. *International Journal of Obesity, 28*(2), 341-341.

Martin, C. K., O'Neil, P. M., & Pawlow, L. (2006). Changes in food cravings during low-calorie and very-low-calorie diets. *Obesity, 14*(1), 115-121.

Martin 2011

Martin, C., Rosenbaum, D., Geiselman, P., Wyatt, H., Klein, S., Hill, J., et al. (2008). Low Carbohydrate and Low Calorie/Low Fat Diets Decrease Cravings and Preferences for Restricted Foods Over Two Years. *Obesity, 16*, S88-S89.

Martin, C. K., McClernon, F. J., Chellino, A., & Correa, J. B. (2011). Food cravings: a central construct in food intake behavior, weight loss, and the neurobiology of appetitive behavior. In V. R. Preedy, R. R. Watson & C. R. Martin (Eds.), *Handbook of Behavior, Food and Nutrition* (pp. 741-755). New York: Springer.

Excluded studies

Akkermann, K., Hiio, K., Villa, I., & Harro, J. (2011). Food restriction leads to binge eating dependent upon the effect of the brain-derived neurotrophic factor Val66Met polymorphism. *Psychiatry Research, 185*(1-2), 39-43.

Alberts, H. J. E. M., Mulkens, S., Smeets, M., & Thewissen, R. (2010). Coping with food cravings. Investigating the potential of a mindfulness-based intervention. *Appetite, 55*(1), 160-163.

Alberts, H. J. E. M., Thewissen, R., & Raes, L. (2012). Dealing with problematic eating behaviour. The effects of a mindfulness-based intervention on eating behaviour, food cravings, dichotomous thinking and body image concern. *Appetite, 58*(3), 847-851.

Benton, D. (2010). The plausibility of sugar addiction and its role in obesity and eating disorders. *Clinical Nutrition, 29*(3), 288-303.

Berridge, K. C. (2009). 'Liking' and 'wanting' food rewards: Brain substrates and roles in eating disorders. *Physiology & Behavior, 97*(5), 537-550.

Blumenthal, D. M., & Gold, M. S. (2010). Neurobiology of food addiction. *Current Opinion in Clinical Nutrition and Metabolic Care, 13*(4), 359-365.

Bodenlos, J. S., Kose, S., Borckardt, J. J., Nahas, Z., Shaw, D., O'Neil, P. M., et al. (2007). Vagus nerve stimulation acutely alters food craving in adults with depression. *Appetite, 48*(2), 145-153.

Brooks, S., Prince, A., Stahl, D., Campbell, I. C., & Treasure, J. (2011). A systematic review and meta-analysis of cognitive bias to food stimuli in people with disordered eating behaviour. *Clinical Psychology Review, 31*(1), 37-51.

Carr, K. D., & Wolinsky, T. D. (1993). Chronic food restriction and weight-loss produce opioid facilitation of perifornical hypothalamic self-stimulation. *Brain Research, 607*(1-2), 141-148.

Cartwright, F., & Stritzke, W. G. K. (2008). A multidimensional ambivalence model of chocolate craving: construct validity and associations with chocolate consumption and disordered eating. *Eating Behaviors, 9*(1), 1-12.

Cartwright, F., Stritzke, W. G. K., Durkin, K., Houghton, S., Burke, V., & Beilin, L. J. (2007). Chocolate craving among children: Implications for disordered eating patterns. *Appetite, 48*(1), 87-95.

Cepeda-Benito, A., Fernandez, M. C., & Moreno, S. (2003). Relationship of gender and eating disorder symptoms to reported cravings for food: construct validation of state and trait craving questionnaires in Spanish. *Appetite, 40*(1), 47-54.

Cepeda-Benito, A., Gleaves, D. H., Fernandez, M. C., Vila, J., Williams, T. L., & Reynoso, J. (2000). The development and validation of Spanish versions of the State and Trait Food Cravings Questionnaires. *Behaviour Research and Therapy, 38*(11), 1125-1138.

Channon, S., & Hayward, A. (1990). The effect of short-term fasting on processing of food cues in normal subjects. *International Journal of Eating Disorders, 9*(4), 447-452.

Cheah, Y. S., Lee, S., Nathan, Y., Ashoor, G., Wilson, B. M., Pernet, A. M., et al. (2011). Both ageing and body mass modulate the human brain response to food cues. *Diabetologia, 54*, S62.

Coelho, J. S., Jansen, A., Roefs, A., & Nederkoom, C. (2009a). Eating behavior in response to food-cue exposure: examining the cue-reactivity and

counteractive-control models. *Psychology of Addictive Behaviors, 23*(1), 131-139.
Coelho, J. S., Polivy, J., & Herman, C. P. (2006). Selective carbohydrate or protein restriction: effects on subsequent food intake and cravings. *Appetite,* (3), 352-360.
Coelho, J. S., Polivy, J., Herman, C. P., & Pliner, P. (2008). Effects of food-cue exposure on dieting-related goals: A limitation to counteractive-control theory. *Appetite, 51*(2), 347-349.
Coelho, J. S., Polivy, J., Herman, C. P., & Pliner, P. (2009b). Wake up and smell the cookies. Effects of olfactory food-cue exposure in restrained and unrestrained eaters. *Appetite, 52*(2), 517-520.
Cohen, I. T., Sherwin, B. B., & Fleming, A. S. (1987). Food cravings, mood and the menstrual cycle. *Hormones and Behavior, 21*(4), 457-470.
Cornier, M.-A., Bechtell, J., Salzberg, A., & Tregellas, J. (2010). The effects of acute energy imbalance on the neuronal response to visual food cues. *Obesity, 18*, S76 (P-128).
Cornier, M.-A., Salzberg, A., Bessesen, D., & Tregellas, J. (2008). Neuronal responses to visual food cues and measures of appetite in obese resistant and obese prone individuals. *Obesity, 16*, S88 (OR-144).
Corwin, R. L., & Grigson, P. S. (2009). Symposium Overview-Food Addiction: Fact or Fiction? *Journal of Nutrition, 139*(3), 617-619.
Cowan, J., & Devine, C. (2008). Food, eating, and weight concerns of men in recovery from substance addiction. *Appetite, 50*(1), 33-42.
Curtis, C. M., Davis, C., & Taylor, V. (2009). Food, my drug of choice: a study investigating predictors of self-proclaimed food addiction. *Obesity, 17*, S119 (253-P).
Dimitropoulos, A., Kennedy, J., & Ho, A. (2010). Differential neural response to food cues during fasting and fed states. *Society for Neuroscience Abstract Viewer and Itinerary Planner, 40*.
Drobes, D. J., Miller, E. J., Hillman, C. H., Bradley, M. M., Cuthbert, B. N., & Lang, P. J. (2001). Food deprivation and emotional reactions to food cues: implications for eating disorders. *Biological Psychology, 57*(1-3), 153-177.
Du, F., Higginbotham, D. A., & White, B. D. (1999). Dose-dependent effects of low dietary protein on food intake, energy balance, and serum leptin. *FASEB Journal, 13*(4), A225-A225.
El-Khatib, F., Rauchenzauner, M., Lechleitner, M., Hoppichler, F., Naser, A., Waldmann, M., et al. (2007). Valproate, weight gain and carbohydrate craving: a gender study. *Seizure, 16*(3), 226-232.
Epstein, S. (1961). Food-related responses to ambiguous stimuli as a function of hunger and ego strength. *Journal of Consulting Psychology, 25*(6), 463-&.
Evans, S. M., Foltin, R. W., & Fischman, M. W. (1999). Food "cravings" and the acute effects of alprazolam on food intake in women with premenstrual dysphoric disorder. *Appetite, 32*(3), 331-349.
Fedoroff, I., Polivy, J., & Herman, C. P. (2003). The specificity of restrained versus unrestrained eaters' responses to food cues: general desire to eat, or craving for the cued food? *Appetite, 41*(1), 7-13.
Finlayson, G., King, N., & Blundell, J. (2007a). Effect of homeostatic and sensory satiety on liking, wanting and food preference. *International Journal of Obesity, 31*, S98 (Abstract T92:PO.83).

Finlayson, G., King, N., & Blundell, J. (2008). The role of implicit wanting in relation to explicit liking and wanting for food: Implications for appetite control. *Appetite, 50*(1), 120-127.
Finlayson, G., King, N., & Blundell, J. E. (2007b). Is it possible to dissociate 'liking' and 'wanting' for foods in humans? A novel experimental procedure. *Physiology & Behavior, 90*(1), 36-42.
Finlayson, G., King, N., & Blundell, J. E. (2007c). Liking vs. wanting food: Importance for human appetite control and weight regulation. *Neuroscience and Biobehavioral Reviews, 31*(7), 987-1002.
Fletcher, B., Pine, K. J., Woodbridge, Z., & Nash, A. (2007). How visual images of chocolate affect the craving and guilt of female dieters. *Appetite, 48*(2), 211-217.
Forman, E. M., Hoffman, K. L., McGrath, K. B., Herbert, J. D., Brandsma, L. L., & Lowe, M. R. (2007). A comparison of acceptance- and control-based strategies for coping with food cravings: An analog study. *Behaviour Research and Therapy, 45*(10), 2372-2386.
Forzano, L.-A. B., Chelonis, J. J., & Casey, C. (2010). Self-control and impulsiveness in nondieting adult human females: effects of visual food cues and deprivation *The Psychological Record, 60*(4), 587-607.
Forzano, L. B., & Corry, R. J. (1998). Self-control and impulsiveness in adult human females: Effects of visual food cues. *Learning and Motivation, 29*(2), 184-199.
Franchina, J. J., & Slank, K. L. (1988). Effects of deprivation on salivary flow in the apparent absence of food stimuli. *Appetite, 10*(2), 143-147.
Fulton, S., Woodside, B., & Shizgal, P. (2002). Does neuropeptide Y contribute to the modulation of brain stimulation reward by chronic food restriction? *Behavioural Brain Research, 134*(1-2), 157-164.
Gadde, K., Foust, M., Yonish, G., & Wagner, H. (2004). The effect of zonisamide on food cravings in a 16-week randomised controlled trial in obese adults. *Obesity Research, 12*, A61-A61.
Gearhardt, A. N., White, M. A., & Potenza, M. N. (2011a). Binge eating disorder and food addiction. *Current Drug Abuse Reviews, 4*(3), 201-207.
Gearhardt, A. N., Yokum, S., Orr, P. T., Stice, E., Corbin, W. R., & Brownell, K. D. (2011b). Neural Correlates of Food Addiction. *Archives of General Psychiatry, 68*(8), 808-816.
Gendall, K. A., Joyce, P. R., & Sullivan, P. F. (1997a). Impact of definition on prevalence of food cravings in a random sample of young women. *Appetite, 28*(1), 63-72.
Gendall, K. A., Joyce, P. R., Sullivan, P. F., & Bulik, C. M. (1998). Food cravers: Characteristics of those who binge. *International Journal of Eating Disorders, 23*(4), 353-360.
Gendall, K. A., Sullivan, P. F., Joyce, P. R., & Bulik, C. M. (1997b). Food cravings in women with a history of anorexia nervosa. *International Journal of Eating Disorders, 22*(4), 403-409.
Gendall, K. A., Sullivan, P. F., Joyce, P. R., Fear, J. L., & Bulik, C. M. (1997c). Psychopathology and personality of young women who experience food cravings. *Addictive Behaviors, 22*(4), 545-555.
Gibson, E. L., & Desmond, E. (1999). Chocolate craving and hunger state: implications for the acquisition and expression of appetite and food

choice. *Appetite, 32*(2), 219-240.
Goldman, R. L., Borckardt, J. J., Frohman, H. A., O'Neil, P. M., Madan, A., Campbell, L. K., et al. (2010). The effectiveness of tDCS in decreasing food cravings. *Obesity, 18*, S103 (253-P).
Goldschmidt, M. H., Elliot, D. L., Goldberg, L., & Moe, E. (2002). More than mood: Is carbohydrate craving related to physical health? *Medicine and Science in Sports and Exercise, 34*(5 Supplement), S194-S194.
Goldstein, R., Hill, S. Y., & Templer, D. I. (1970). Effect of food deprivation on hypothalamic self-stimulation in stimulus-bound eater and non-eaters. *Physiology & Behavior, 5*(8), 915-918.
Gordon, C. M., & Spence, D. P. (1966). Facilitating effects of food set and food deprivation on responses to a subliminal food stimulus. *Journal of Personality, 34*(3), 406.
Grothe, K., Roach, J., Low, A., Dubbert, P., & Schenk, M. (2008). Sedentary behavior and food cravings in diverse overweight women. *Obesity, 16*, S200 (527-P).
Hachl, P., & Pietrowsky, R. (2001). ERPs to the processing of food stimuli in restrained and unrestrained eaters. *Psychophysiology, 38*, S47-S47.
Harvey, K., Kemps, E., & Tiggemann, M. (2005). The nature of imagery processes underlying food cravings. *British Journal of Health Psychology, 10*, 49-56.
Hawk, L. W., Baschnagel, J. S., Ashare, R. L., & Epstein, L. H. (2004). Craving and startle modification during in vivo exposure to food cues. *Appetite, 43*(3), 285-294.
Hawks, S., Madanat, H., & Christley, H. (2008). Psychosocial associations of dietary restraint: Implications for healthy weight promotion. *Ecology of Food and Nutrition, 47*, 450-483.
Heller, R. F. (1994). Hyperinsulinemic obesity and carbohydrate addiction: the missing link is the carbohydrate frequency factor. *Medical Hypotheses, 42*(5), 307-312.
Hetherington, M., & Macdiarmid, J. (1995). The pleasure of eating: Chocolate addiction explored. *Appetite*, 83 (Abstract).
Hetherington, M. M., & Macdiarmid, J. I. (1993). Chocolate addiction - a preliminary study of its description and its relationship to problem eating. *Appetite, 21*(3), 233-246.
Hill, A. J. (2007). Symposium on 'molecular mechanisms and psychology of food intake' - The psychology of food craving. *Proceedings of the Nutrition Society, 66*(2), 277-285.
Hill, A. J., & Heatonbrown, L. (1994). The experience of food craving - a prospective investigation in healthy women. *Journal of Psychosomatic Research, 38*(8), 801-814.
Hill, A. J., Weaver, C. F. L., & Blundell, J. E. (1991). Food craving, dietary restraint and mood. *Appetite, 17*(3), 187-197.
Hooper, N., Sandoz, E. K., Ashton, J., Clarke, A., & McHugh, L. (2012). Comparing thought suppression and acceptance as coping techniques for food cravings. *Eating Behaviors, 13*(1), 62-64.
Hormes, J. M., & Timko, C. A. (2011). All cravings are not created equal. Correlates of menstrual versus non-cyclic chocolate craving. *Appetite, 57*(1), 1-5.
Hoyenga, K. T., & Hoyenga, K. B. (1974). Effects of food-deprivation upon cue

utilization as measured by novelty-incentive. *Quarterly Journal of Experimental Psychology, 26*(MAY), 206-217.
James, G. A., Gold, M. S., & Liu, Y. J. (2004). Interaction of satiety and reward response to food stimulation. *Journal of Addictive Diseases, 23*(3), 23-37.
Jauregui Lobera, I., Bolanos, P., Carbonero, R., & Valero Blanco, E. (2010). Psychometric properties of the Spanish version of Food Craving Inventory (FCI-SP). *Nutricion Hospitalaria, 25*(6), 984-992.
Juarascio, A., Forman, E., Timko, C. A., Butryn, M., & Goodwin, C. (2011). The development and validation of the food craving acceptance and action questionnaire (FAAQ). *Eating Behaviors, 12*(3), 182-187.
Kemps, E., & Tiggemann, M. (2007). Modality-specific imagery reduces cravings for food: An application of the elaborated intrusion theory of desire to food craving. *Journal of Experimental Psychology: Applied, 13*(2), 95-104.
Kemps, E., & Tiggemann, M. (2009). Attentional bias for craving-related (chocolate) food cues. *Experimental and clinical psychopharmacology, 17*(6), 425-433.
Kemps, E., Tiggermann, M., Woods, D., & Soekov, B. (2004). Reduction of food cravings through concurrent visuospatial processing. *International Journal of Eating Disorders, 36*(1), 31-40.
Kemps, E., Tiggernann, M., & Christianson, R. (2008). Concurrent visuo-spatial processing reduces food cravings in prescribed weight-loss dieters. *Journal of Behavior Therapy and Experimental Psychiatry, 39*(2), 177-186.
Kennedy, J., Ho, A., & Dimitropoulos, A. (2010). Correlations of body mass index with neurological activity to food cues when hungry and satiated. *Society for Neuroscience Abstract Viewer and Itinerary Planner, 40*.
Komatsu, S. (2008). Rice and sushi cravings: A preliminary study of food craving among Japanese females. *Appetite, 50*(2-3), 353-358.
Kristeller, J. L., & Schwartz, G. E. (1982). Facial responsiveness to food and non-food cues in restrained and unrestrained eaters. *Psychophysiology, 19*(3), 331 (abstract).
Landis, A. M., & Parker, K. P. (2008). Sleep, hunger, satiety, food cravings, and caloric intake in adolescents. *Sleep, 31*, A72-A72.
Landis, A. M., Parker, K. P., & Dunbar, S. B. (2009). Sleep, Hunger, Satiety, Food Cravings, and Caloric Intake in Adolescents. *Journal of Nursing Scholarship, 41*(2), 115-123.
Leland, D., & Pineda, J. (2002). Food cue effects on ERPs and target reaction times in fasting subjects. *Journal of Cognitive Neuroscience*, 123-124.
Leland, D. S., & Pineda, J. A. (2006). Effects of food-related stimuli on visual spatial attention in fasting and nonfasting normal subjects: Behavior and electrophysiology. *Clinical Neurophysiology, 117*(1), 67-84.
Lemmens, S. G., Born, J. M., Rutters, F., Schoffelen, P. F., Wouters, L., & Westerterp-Plantenga, M. S. (2010). Dietary restraint and control over wanting following consumption of forbidden food. *Obesity, 18*(10), 1926-1931.
Lemmens, S. G., Rutters, F., Born, J. M., & Westerterp-Plantenga, M. S. (2011). Stress augments food 'wanting' and energy intake in visceral overweight subjects in the absence of hunger. *Physiology & Behavior, 103*(2), 157-163.
Lim, S. S., Norman, R. J., Clifton, P. M., & Noakes, M. (2009). Hyperandrogenemia, psychological distress, and food cravings in young women. *Physiology &*

Behavior, 98(3), 276-280.
Martin, C., Greenway, F., O'Neil, P., Anderson, J., Fujioka, K., Gadde, K., et al. (2003a). The effect of bupropion on food craving over 24 weeks in a multicenter weight loss trial. *Obesity Research, 11*, A98-A98.
Martin, C., Greenway, F., White, M., & Ortego, L. (2003b). The effect of ecopipam on food cravings and binge eating pathology during a six-month weight loss trial. *Obesity Research, 11*, A96-A97.
Martin, C., Williamson, D., Mickley, N., & Greenway, F. (2000). Food cravings and consumption of a high fat, high sugar food: Gender and ethnic differences. *Obesity Research, 8*, 42S-42S.
Martin, C. K., O'Neil, P. M., & Pawlow, L. (2006). Changes in food cravings during low-calorie and very-low-calorie diets. *Obesity, 14*(1), 115-121.
Martin, C. K., Rosenbaum, D., Han, H., Geiselman, P. J., Wyatt, H. R., Hill, J. O., et al. (2011). Change in food cravings, food preferences, and appetite during a low-carbohydrate and low-fat diet. *Obesity (Silver Spring), 19*(10), 1963-1970.
Massey, A., & Hill, A. (2004). Dieting and food craving: A quasi-prospective study. *International Journal of Obesity, 28*(Suppl. 1), S213 (Abstract T217d:P217d-001).
Massey, A., & Hill, A. J. (2012). Dieting and food craving. A descriptive, quasi-prospective study. *Appetite, 58*(3), 781-785.
Mauler, B. I., Hamm, A. O., Weike, A. I., & Tuschen-Caffier, B. (2006). Affect regulation and food intake in bulimia nervosa: Emotional responding to food cues after deprivation and subsequent eating. *Journal of Abnormal Psychology, 115*(3), 567-579.
McCrory, M. A., Lovejoy, J. C., Palmer, P. A., Eichelsdoerfer, P. E., Gehrke, M. M., & Kavanaugh, I. T. (2010). A randomized study of legume consumption during weight loss: Effects on food cravings. *FASEB Journal. Conference: Experimental Biology, 24*(Meeting Abstract Supplement), 95.92.
Mercer, M. E., & Holder, M. D. (1997). Food cravings, endogenous opioid peptides, and food intake: A review. *Appetite, 29*(3), 325-352.
Meule, A., & Kuebler, A. (2012a). Food cravings in food addiction: The distinct role of positive reinforcement. *Eating Behaviors, 13*(3), 252-255.
Meule, A., Lutz, A., Voegele, C., & Kuebler, A. (2012b). Food cravings discriminate differentially between successful and unsuccessful dieters and non-dieters. Validation of the Food Cravings Questionnaires in German. *Appetite, 58*(1), 88-97.
Meule, A., Westenhoefer, J., & Kuebler, A. (2011). Food cravings mediate the relationship between rigid, but not flexible control of eating behavior and dieting success. *Appetite, 57*(3), 582-584.
Moreno, S., Rodriguez, S., Carmen Fernandez, M., Tamez, J., & Cepeda-Benito, A. (2008). Clinical validation of the trait and state versions of the Food Craving Questionnaire. *Assessment, 15*(3), 375-387.
Moreno, S., Rodriguez, S., Vera, M. N., Fernandez, M. C., & Vila, J. (2006). Physiological and behavioral assessment of food craving in bulimia nervosa. [Abstracts of the 5th Congress of the Spanish Society of Psychophysiology (SEPF), Granada, Spain, September 28–30, 2006: Posters]. *Journal of Psychophysiology, 20*(3), 242-243.
Moreno, S., Warren, C. S., Rodriguez, S., Carmen Fernandez, M., & Cepeda-Benito,

A. (2009). Food cravings discriminate between anorexia and bulimia nervosa. Implications for "success" versus "failure" in dietary restriction. *Appetite, 52*(3), 588-594.
Moreno-Dominguez, S., Rodriguez-Ruiz, S., Martin, M., & Warren, C. S. (2012). Experimental effects of chocolate deprivation on cravings, mood, and consumption in high and low chocolate-cravers. *Appetite, 58*(1), 111-116.
Neithercott, T. (2012). Temptation strikes. What makes us crave foods--and how to fight back. *Diabetes Forecast, 65*(3), 46-49.
Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2007). The modified Trait and State Food-Cravings Questionnaires: Development and validation of a general index of food craving. *Appetite, 49*(1), 38-46.
Osman, J. L., & Sobal, J. (2006). Chocolate cravings in American and Spanish individuals: Biological and cultural influences. *Appetite, 47*(3), 290-301.
Pelchat, M. L., Johnson, A., Chan, R., Valdez, J., & Ragland, J. D. (2004). Images of desire: food-craving activation during fMRI. *Neuroimage, 23*(4), 1486-1493.
Pietrowsky, R., Straub, K., & Hachl, P. (2003). Body dissatisfaction in female restrained eaters depends on food deprivation. *Appetite, 40*(3), 285-290.
Polivy, J., Coleman, J., & Herman, C. P. (2005). The effect of deprivation on food cravings and eating behavior in restrained and unrestrained eaters. *International Journal of Eating Disorders, 38*(4), 301-309.
Polivy, J., Herman, C. P., & Coelho, J. S. (2008). Caloric restriction in the presence of attractive food cues: External cues, eating, and weight. *Physiology & Behavior, 94*(5), 729-733.
Rejeski, W. J., Burdette, J., Burns, M., Morgan, A. R., Hayasaka, S., Norris, J., et al. (2012). Power of food moderates food craving, perceived control, and brain networks following a short-term post-absorptive state in older adults. *Appetite, 58*(3), 806-813.
Rodin, J., Mancuso, J., Granger, J., & Nelbach, E. (1991). Food cravings in relation to body-mass index, restraint and estradiol levels - a repeated measures study in healthy women. *Appetite, 17*(3), 177-185.
Rogers, P. J., & Hill, A. J. (1989). Breakdown of dietary restraint following mere exposure to food stimuli: interrelationships between restraint, hunger, salivation, and food intake. *Addictive Behaviors, 14*(4), 387-397.
Rosenbaum, M., Sy, M., Pavlovich, K., Leibel, R. L., & Hirsch, J. (2008). Leptin reverses weight loss-induced changes in regional neural activity responses to visual food stimuli. *Journal of Clinical Investigation, 118*(7), 2583-2591.
Schlundt, D. G., Virts, K. L., Sbrocco, T., Popecordle, J., & Hill, J. O. (1993). A sequential behavioral analysis of craving sweets in obese women. *Addictive Behaviors, 18*(1), 67-80.
Sitton, S. C. (1991). Role of craving for carbohydrates upon completion of a protein-sparing fast. *Psychological Reports, 69*(2), 683-686.
Spence, D. P., & Ehrenberg, B. (1964). Effects of oral deprivation on responses to subliminal and supraliminal verbal food stimuli
. *Journal of Abnormal and Social Psychology, 69*(1), 10-18.
Steel, D., Kemps, E., & Tiggemann, M. (2006). Effects of hunger and visuo-spatial interference on imagery-induced food cravings. *Appetite, 46*(1), 36-40.
Strachan, M. W. J., Ewing, F. M. E., Frier, B. M., Harper, A., & Deary, I. J. (2004).

Food cravings during acute hypoglycaemia in adults with Type 1 diabetes. *Physiology & Behavior, 80*(5), 675-682.
Stuart, D. M. (1962). TO DEPRESS THE CRAVING FOR FOOD. *American Journal of Nursing, 62*(3), 88-92.
Teegarden, S. L., & Bale, T. L. (2004). Withdrawal from a high fat diet: Obesity as a stress-sensitive disease of addiction. *Neuropsychopharmacology, 29*, S88-S89.
Uher, R., Treasure, J., Heining, M., Brammer, M. J., & Campbell, I. C. (2006). Cerebral processing of food-related stimuli: Effects of fasting and gender. *Behavioural Brain Research, 169*(1), 111-119.
Warren, C., & Cooper, P. J. (1988). Psychological effects of dieting. *Br J Clin Psychol, 27 (Pt 3)*, 269-270.
Waters, A., Hill, A., & Waller, G. (2001). Bulimics' responses to food cravings: is binge-eating a product of hunger or emotional state? *Behaviour Research and Therapy, 39*(8), 877-886.
Weingarten, H. P. (1991a). Cravings for foods - 4 new studies *Appetite, 17*(3), 165-166.
Weingarten, H. P., & Elston, D. (1990). The phenomenology of food cravings. *Appetite, 15*(3), 231-246.
Weingarten, H. P., & Elston, D. (1991b). Food cravings in a college population. *Appetite, 17*(3), 167-175.
Westman, E. C., Edman, J. S., Tomlin, K. F., & Perkins, C. P. (2000). Preliminary evidence for carbohydrate addiction during a very-low-carbohydrate diet and nutritional supplement program. *Journal of the American College of Nutrition, 19*(5), 697 (abstract).
White, M. A., & Grilo, C. M. (2005). Psychometric properties of the Food Craving Inventory among obese patients with binge eating disorder. *Eating Behaviors, 6*(3), 239-245.
White, M. A., Whisenhunt, B. L., Williamson, D. A., Greenway, F. L., & Netemeyer, R. G. (2002). Development and validation of the Food-Craving Inventory. *Obesity Research, 10*(2), 107-114.
Yang, Q. (2010). Gain weight by "going diet?" Artificial sweeteners and the neurobiology of sugar cravings. *Yale Journal of Biology and Medicine, 83*(2), 101-108.

Other studies

Caballero, B. (1987). Brain serotonin and carbohydrate craving in obesity. *International Journal of Obesity, 11 Suppl 3*, 179-183.
Wurtman, J. J. (1990). Carbohydrate craving: relationship between carbohydrate intake and disorders of mood. *Drugs, 39*, 49-52.
Wurtman, R. J. (1987). Food consumption, 5-HT neurons, appetite control, and carbohydrate cravings. *International Journal of Obesity, 11*, 24-24.
Zarcone, T. J., Hienz, R. D., & Brady, J. V. (1997). Behavioral indices of food craving: A potential model for drug craving. *Integrative Physiological and Behavioral Science, 32*(2), 194-194.

Additional references

Bacon, L., & Aphramor, L. (2011). Weight science: evaluating the evidence for a paradigm shift. *Nutrition Journal, 10*, 9.

Bjorvell, H., Ronnberg, S., & Rossner, S. (1985). Eating patterns described by a group of treatment seeking overweight women and normal weight women. *Scandinavian Journal of Behaviour Therapy, 14*(4), 147-156.

Cepeda-Benito, A., Gleaves, D. H., Williams, T. L., & Erath, S. A. (2000). The development and validation of the state and trait food-cravings questionnaires. *Behavior Therapy, 31*(1), 151-173.

Cornier, M. A. (2011). Is your brain to blame for weight regain? *Physiology & Behavior, 104*(4), 608-612.

Corsica, J. A., & Spring, B. J. (2008). Carbohydrate craving: A double-blind, placebo-controlled test of the self-medication hypothesis. *Eating Behaviors, 9*(4), 447-454.

Das, S. K., Gilhooly, C. H., Golden, J. K., Pittas, A. G., Fuss, P. J., Cheatham, R. A., et al. (2007). Long-term effects of 2 energy-restricted diets differing in glycemic load on dietary adherence, body composition, and metabolism in CALERIE: a 1-y randomized controlled trial. *American Journal of Clinical Nutrition, 85*(4), 1023-1030.

Deeks, J. J., Dinnes, J., D'Amico, R., Sowden, A. J., Sakarovitch, C., Song, F., et al. (2003). Evaluating non-randomised intervention studies. *Health Technology Assessment, 7*(27), iii-x, 1-173.

Delahanty, L., Meigs, J. B., Hayden, D., Williamson, D. A., Nathan, D. M., & Grp, D. R. (2002). Psychological and behavioral correlates of baseline BMI in the Diabetes Prevention Program (DPP). *Diabetes Care, 25*(11), 1992-1998.

Fabbricatore, M., Imperatori, C., Morgia, A., Contardi, A., Tamburello, S., Innamorati, M., et al. (2011). Food craving and personality dimensions in overweight and obese patients attending low energy diet therapy. *Obesity and Metabolism-Milan, 7*(1), E28-E34.

Fabbricatore, M., Imperatori, C., Pecchioli, L., Micarelli, T., Contardi, A., Tamburello, S., et al. (2011). Binge eating and BIS/BAS activity in obese patients with intense food craving who attend weight control programs. *Obesity and Metabolism-Milan, 7*(1), E21-E27.

Fabricatore, A. N., Wadden, T. A., Higginbotham, A. J., Faulconbridge, L. F., Nguyen, A. M., Heymsfield, S. B., et al. (2011). Intentional weight loss and changes in symptoms of depression: a systematic review and meta-analysis. *International Journal of Obesity, 35*(11), 1363-1376.

Faith, M. S., Butryn, M., Wadden, T. A., Fabricatore, A., Nguyen, A. M., & Heymsfield, S. B. (2011). Evidence for prospective associations among depression and obesity in population-based studies. *Obesity Reviews, 12*(5), e438-453.

Foster, G. D., Wyatt, H. R., Hill, J. O., Makris, A. P., Rosenbaum, D. L., Brill, C., et al. (2010). Weight and Metabolic Outcomes After 2 Years on a Low-Carbohydrate Versus Low-Fat Diet A Randomized Trial. *Annals of Internal Medicine, 153*(3), 147-U137.

Gendall, K. A., Joyce, P. R., & Sullivan, P. F. (1997). Impact of definition on prevalence of food cravings in a random sample of young women. *Appetite, 28*(1), 63-72.

Gibson, E. L., & Desmond, E. (1999). Chocolate craving and hunger state: implications for the acquisition and expression of appetite and food choice. *Appetite, 32*(2), 219-240.
Gilhooly, C. H., Das, S. K., Golden, J. K., McCrory, M. A., Dallal, G. E., Saltzman, E., et al. (2007). Food cravings and energy regulation: The characteristics of craved foods and their relationship with eating behaviors and weight change during 6 months of dietary energy restriction. *International Journal of Obesity, 31*(12), 1849-1858.
Greenway, F. L., Fujioka, K., Plodkowski, R. A., Mudaliar, S., Guttadauria, M., Erickson, J., et al. (2010). Effect of naltrexone plus bupropion on weight loss in overweight and obese adults (COR-I): a multicentre, randomised, double-blind, placebo-controlled, phase 3 trial. *Lancet, 376*(9741), 595-605.
Grosshans, M., Vollmert, C., Vollstadt-Klein, S., Tost, H., Leber, S., Bach, P., et al. (2012). Association of leptin with food cue-induced activation in human reward pathways. *Archives of General Psychiatry, 69*(5), 529-537.
Hall, D. M., & Most, M. M. (2005). Dietary adherence in well-controlled feeding studies. *Journal of the American Dietetic Association, 105*(8), 1285-1288.
Harvey, J., Wing, R. R., & Mullen, M. (1993). Effects on food cravings of a very low calorie diet or a balanced, low calorie diet. *Appetite, 21*(2), 105-115.
Herman, C. P., & Polivy, J. (1980). Restrained eating. In A. J. Stunkard (Ed.), *Obesity* (pp. 208-225). Philadelphia: Saunders.
Hession, M., Rolland, C., Kulkarni, U., Wise, A., & Broom, J. (2009). Systematic review of randomized controlled trials of low-carbohydrate vs. low-fat/low-calorie diets in the management of obesity and its comorbidities. *Obesity reviews : an official journal of the International Association for the Study of Obesity, 10*(1), 36-50.
Hill, A. (2002). Prevalence and demographics of dieting. In C. Fairburn & K. Brownell (Eds.), *Eating disorders and obesity. A comprehensive handbook* (2nd ed.). New York: Guilford.
Hill, A. J. (2007). Symposium on 'molecular mechanisms and psychology of food intake' - The psychology of food craving. *Proceedings of the Nutrition Society, 66*(2), 277-285.
Hill, A. J., & Heaton-Brown, L. (1994). The experience of food craving - a prospective investigation in health women. *Journal of Psychosomatic Research, 38*(8), 801-814.
Hill, A. J., Weaver, C. F. L., & Blundell, J. E. (1991). Food craving, dietary restraint and mood. *Appetite, 17*(3), 187-197.
Hormes, J. M., & Rozin, P. (2010). Does "craving" carve nature at the joints? Absence of a synonym for craving in many languages. *Addictive Behaviors, 35*(5), 459-463.
Keys, A., Brozek, J., Henschel, A., Mickelsen, O., & Taylor, H. (1950). *The biology of human starvation*. Oxford: University of Minnesota Press.
Kissileff, H. R., Thornton, J. C., Torres, M. I., Pavlovich, K., Mayer, L. S., Kalari, V., et al. (2012). Leptin reverses declines in satiation in weight-reduced obese humans. *The American Journal of Clinical Nutrition, 95*(2), 309-317.
Klinitzke, G., Steinig, J., Bluher, M., Kersting, A., & Wagner, B. (2012). Obesity and suicide risk in adults-A systematic review. *Journal of Affective Disorders, Epub ahead of print*.

Komatsu, S. (2008). Rice and sushi cravings: A preliminary study of food craving among Japanese females. *Appetite, 50*(2-3), 353-358.
Lappalainen, R., Sjoden, P. O., Hursti, T., & Vesa, V. (1990). Hunger/craving responses and reactivity to food stimuli during fasting and dieting. *International Journal of Obesity, 14*(8), 679-688.
Lowe, M. R., & Butryn, M. L. (2007). Hedonic hunger: a new dimension of appetite? *Physiology & Behavior, 91*(4), 432-439.
Mann, T., Tomiyama, A. J., Westling, E., Lew, A. M., Samuels, B., & Chatman, J. (2007). Medicare's search for effective obesity treatments: diets are not the answer. *The American Psychologist, 62*(3), 220-233.
Martin, C. K., McClernon, F. J., Chellino, A., & Correa, J. B. (2011). Food cravings: a central construct in food intake behavior, weight loss, and the neurobiology of appetitive behavior. In V. R. Preedy, R. R. Watson & C. R. Martin (Eds.), *Handbook of Behavior, Food and Nutrition* (pp. 741-755). New York: Springer.
Martin, C. K., O'Neil, P. M., & Pawlow, L. (2006). Changes in food cravings during low-calorie and very-low-calorie diets. *Obesity, 14*(1), 115-121.
Martin, C. K., Rosenbaum, D., Han, H., Geiselman, P. J., Wyatt, H. R., Hill, J. O., et al. (2011). Change in food cravings, food preferences, and appetite during a low-carbohydrate and low-fat diet. *Obesity, 19*(10), 1963-1970.
Massey, A., & Hill, A. J. (2012). Dieting and food craving. A descriptive, quasi-prospective study. *Appetite, 58*(3), 781-785.
Meule, A., Lutz, A., Voegele, C., & Kuebler, A. (2012). Food cravings discriminate differentially between successful and unsuccessful dieters and non-dieters. Validation of the Food Cravings Questionnaires in German. *Appetite, 58*(1), 88-97.
Michener, W., & Rozin, P. (1994). Pharmacological versus sensory factors in the satiation of chocolate craving. *Physiology & Behavior, 56*(3), 419-422.
Muennig, P., Jia, H., Lee, R., & Lubetkin, E. (2008). I think therefore I am: perceived ideal weight as a determinant of health. *American Journal of Public Health, 98*(3), 501-506.
Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2007). The modified Trait and State Food-Cravings Questionnaires: Development and validation of a general index of food craving. *Appetite, 49*(1), 38-46.
Ogden, L. G., Stroebele, N., Wyatt, H. R., Catenacci, V. A., Peters, J. C., Stuht, J., et al. (2012). Cluster analysis of the national weight control registry to identify distinct subgroups maintaining successful weight loss. *Obesity, 20*(10), 2039-2047.
Osman, J. L., & Sobal, J. (2006). Chocolate cravings in American and Spanish individuals: Biological and cultural influences. *Appetite, 47*(3), 290-301.
Parker, S., Kamel, N., & Zellner, D. (2003). Food craving patterns in Egypt: comparisons with North America and Spain. *Appetite, 40*(2), 193-195.
Pelchat, M. L. (1997). Food cravings in young and elderly adults. *Appetite, 28*(2), 103-113.
Pelchat, M. L., & Schaefer, S. (2000). Dietary monotony and food cravings in young and elderly adults. *Physiology & Behavior, 68*(3), 353-359.
Phelan, S., Hill, J. O., Lang, W., Dibello, J. R., & Wing, R. R. (2003). Recovery from relapse among successful weight maintainers. *The American Journal of Clinical Nutrition, 78*(6), 1079-1084.

Polivy, J. (1996). Psychological consequences of food restriction. *Journal of the American Dietetic Association, 96*(6), 589-592.
Polivy, J., Coleman, J., & Herman, C. P. (2005). The effect of deprivation on food cravings and eating behavior in restrained and unrestrained eaters. *International Journal of Eating Disorders, 38*(4), 301-309.
Rankin, H., Hodgson, R., & Stockwell, T. (1979). Concept of craving and its measurement. *Behaviour Research and Therapy, 17*(4), 389-396.
Rideout, C. A., & Barr, S. I. (2009). "Restrained Eating" vs "Trying to Lose Weight": How are they associated with body weight and tendency to overeat among postmenopausal women? *Journal of the American Dietetic Association, 109*(5), 890-893.
Rolland, C., Hession, M., & Broom, I. (2011). Effect of weight loss on adipokine levels in obese patients. *Diabetes, Metabolic Syndrome and Obesity : Targets and Therapy, 4*, 315-323.
Rosenbaum, M., Kissileff, H. R., Mayer, L. E., Hirsch, J., & Leibel, R. L. (2010). Energy intake in weight-reduced humans. *Brain Research, 1350*, 95-102.
Sitton, S. C. (1991). Role of craving for carbohydrates upon completion of a protein-sparing fast. *Psychological Reports, 69*(2), 683-686.
Smit, H. J., Gaffan, E. A., & Rogers, P. J. (2004). Methylxanthines are the psycho-pharmacologically active constituents of chocolate. *Psychopharmacology, 176*(3-4), 412-419.
Speakman, J. R., Levitsky, D. A., Allison, D. B., Bray, M. S., de Castro, J. M., Clegg, D. J., et al. (2011). Set points, settling points and some alternative models: theoretical options to understand how genes and environments combine to regulate body adiposity. *Disease Models & Mechanisms, 4*(6), 733-745.
Stice, E., Sysko, R., Roberto, C. A., & Allison, S. (2010). Are dietary restraint scales valid measures of dietary restriction? Additional objective behavioral and biological data suggest not. *Appetite, 54*(2), 331-339.
The Cochrane Collaboration. (2011). Cochrane Handbook for Systematic Reviews of Interventions. In J. Higgins & S. Green (Eds.) Available from www.cochrane-handbook.org
Toll, B. A., Katulak, N. A., Williams-Piehota, P., & O'Malley, S. (2008). Validation of a scale for the assessment of food cravings among smokers. *Appetite,* (1), 25-32
Vander Wal, J. S., Johnston, K. A., & Dhurandhar, N. V. (2007). Psychometric properties of the State and Trait Food Cravings Questionnaires among overweight and obese persons. *Eating Behaviors, 8*(2), 211-223.
Weingarten, H. P., & Elston, D. (1990). The phenomenology of food cravings. *Appetite, 15*(3), 231-246.
Weingarten, H. P., & Elston, D. (1991). Food cravings in a college population. *Appetite, 17*(3), 167-175.
White, M. A., & Grilo, C. M. (2005). Psychometric properties of the Food Craving Inventory among obese patients with binge eating disorder. *Eating Behaviors, 6*(3), 239-245.
White, M. A., Whisenhunt, B. L., Williamson, D. A., Greenway, F. L., & Netemeyer, R. G. (2002). Development and validation of the Food-Craving Inventory. *Obesity Research, 10*(2), 107-114.
Wilcox, C. S., Oskooilar, N., Erickson, J. S., Billes, S. K., Katz, B. B., Tollefson, G., et al. (2010). An open-label study of naltrexone and bupropion combination

therapy for smoking cessation in overweight and obese subjects. *Addictive Behaviors, 35*(3), 229-234.
Williamson, D. A., Martin, C. K., York-Crowe, E., Anton, S. D., Redman, L. M., Han, H., et al. (2007). Measurement of dietary restraint: validity tests of four questionnaires. *Appetite, 48*(2), 183-192.
Wing, R. R., Blair, E., Marcus, M., Epstein, L. H., & Harvey, J. (1994). Year-long weight-loss treatment for obese patients with type-II diabetes - does including an intermittent very-low-calorie diet improve outcome. *American Journal of Medicine, 97*(4), 354-362.

Appendix 1. Search strategy

MEDLINE and Embase

1. crav*.ti,ab
2. cue*.ti
3. addict*.ti
4. stimul*.ti
5. depend*.ti
6. want*.ti
7. or/1-6
8. carbohydrate*.ti
9. protein*.ti
10. fat*.ti
11. sugar*.ti
12. chocolate*.ti
13. sweet*.ti
14. food*.ti
15. or/8-14
16. 7 and 15
17. (alcohol* OR cocaine* OR amphetamine* or methamphetamine* OR smok* OR nicotine OR tobacco OR marijuana OR heroin).mp
18. 16 not 17
19. feeding behaviour.mp. or exp Feeding behaviour/
20. eating.mp or exp Eating/
21. food.mp. or exp Food/

22. Diet, Fat-Restricted/ or exp Diet/ or Ketogenic Diet/ or Diet, Carbohydrate-Restricted/ or diet.mp. or Diet, Reducing/ or Diet Therapy/
23. Restrict*.ti,ab.
24. Restrain*.ti,ab
25. Depriv*.ti,ab.
26. Reduc*.ti,ab.
27. (weight loss or weightloss).mp.
28. calor*.ti,ab.
29. Hypocalor*.ti,ab
30. Exp Weight Loss/
31. Exp Energy Intake/
32. Or/19-31
33. 18 and 32
34. Limit 33 to (English language and humans and "therapy [maximizes sensitivity]")

Web of Knowledge, Science Citation Index

1. Title=(crav* OR cue* OR addict* OR depend* OR want*); AND
2. Title=(carbohydrate* OR fat* OR protein* OR sugar* OR sweet* OR chocolate* OR food*); AND
3. Topic=(weightloss OR weight loss OR eat* OR food* OR diet*); NOT
4. Title=(alcohol* OR cocaine* OR amphetamine* OR methamphetamine* OR smok* OR nicotin* OR tobacco OR marijuana OR heroin); NOT

5. Title=(mice OR mouse OR rat OR rodent* OR fish* OR bird* OR worm); AND
6. Research domains=(Science technology); AND
7. Research Areas=(Nutrition Dietetics OR Behavioral Sciences OR Public Environmental Occupational Health OR Psychology OR Sports Sciences); AND
8. Document Types=(Article OR Meeting OR Abstract OR Clinical Trial); AND
9. Languages=(English)
10. Timespan=All Years

Cochrane Library

Terms for cravings AND macronutrients/food types AND restrictive dieting, as above. No limits were applied.

Appendix 2. Characteristics of Included Studies

Study ID	Fabbricatore 2011a
Title	Food craving and personality dimensions in overweight and obese patients attending low energy diet therapy
Authors	Fabbricatore M, Imperatori C, Morgia A, Contardi A, Tamburello S, Innamorati M, Tamburello A.
Country	Italy
Methods	DESIGN: Parent study – non-randomised comparative study; cravings data used in this review – cross-sectional SAMPLING: Consecutive overweight/obese patients attending low-energy diet therapy in two private medical centres. INCLUSION CRITERIA: Age 18+; BMI ≥ 25 kg/m^2 EXCLUSION CRITERIA: Dieting > 4 weeks, major CNS disorder, psychotic symptoms, major mood disorders DURATION: Not applicable DROPOUTS: Not applicable ANALYSIS: *t*-tests for between-group differences

Study ID	Fabbricatore 2011a /cont.
Participants	N: 55 (Dieters n=27; non-dieters n=28) AGE: 39.4 years WOMEN: 76.4% BMI: 30.1±4.4 kg/m^2 Demographic data not presented separately for dieters/non-dieters.
Diet intervention	DIETERS: Low-calorie (500–1000 kcal/d deficit) or very-low-calorie (not defined) diets. Number of each diet type not reported. Dieters analysed as one group, not by diet type CONTROL: Current overweight/obese non-dieters ADHERENCE: Not assessed
Outcomes	CRAVINGS MEASURES: Food Cravings Questionnaire – Trait (Cepeda-Benito et al., 2000) OTHER: Temperament and Character Inventory Revised

Study ID	Fabbricatore 2011a /cont.	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Comparability of groups at baseline	Parent study compared overweight with normal weight controls. Dieters/non-dieters were subsets of the overweight group. Baseline data not reported separately for dieters/non-dieters.	Unclear risk of bias
Allocation	Unclear how patients were assigned to different diet interventions. Possibly by diet centre attended.	Unclear risk of bias
Performance bias		
Blinding of participants and personnel	Not possible to blind participants to diet intervention. Blinding of study staff not reported. Comment: Probably not done. Potential impact on outcome unclear, but unlikely.	Low risk of bias

Study ID	Fabbricatore 2011a /cont.	
Detection bias		
Blinding of outcome assessment	Not applicable – all outcome measures self-reported	Not applicable
Attrition bias		
Incomplete outcome data	Not applicable – cross-sectional study	Not applicable
Reporting bias		
Selective reporting	All outcome measures reported	Low risk of bias
Other bias		
Other sources of bias	None	Not applicable

Study ID	Fabbricatore 2011b
Title	Binge eating and BIS/BAS activity in obese patients with intense food cravings who attend weight control programs
Authors	Fabbricatore M, Imperatori C, Morgia A, Contardi A, Tamburello S, Innamorati M, Tamburello A.
Country	Italy
Methods	DESIGN: Parent study – non-randomised comparative study; cravings data used in this review – cross-sectional SAMPLING: Consecutive overweight/obese patients attending low-energy diet therapy in two private medical centres. INCLUSION CRITERIA: Age 18+; BMI ≥ 25 kg/m^2 EXCLUSION CRITERIA: Major CNS disorder, psychotic symptoms, major mood disorders DURATION: Not applicable DROPOUTS: Not applicable ANALYSIS: T-tests for between-group differences; one-way Fisher exact tests for 2x2 contingency tables; variables significantly associated with craving groups inserted as independent variables in a logistic regression analysis.

Study ID	Fabbricatore 2011b /cont.
Participants	N: 102 AGE: 45.1 years WOMEN: 84.3% BMI: 32.8 kg/m^2 Demographic data not presented separately for dieters/non-dieters.
Diet intervention	DIETERS (n=57): Low-calorie (500–1000 kcal/d deficit) or very-low-calorie (not defined) diets. Number of each diet type not reported. Dieters not analysed by diet type. 47/57 had been dieting ≥ 4 weeks; 10/57 had been dieting < 4 weeks. CONTROL: (n=45): Current overweight/obese non-dieters ADHERENCE: Not assessed
Outcomes	CRAVINGS MEASURES: Food Cravings Questionnaire – Trait (Cepeda-Benito et al., 2000) OTHER: BIS/BAS Scale, Binge Eating Scale

Study ID	Fabbricatore 2011b /cont.	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Comparability of groups at baseline	Study compared various personality and clinical measures in individuals with either intense or mild food cravings. Baseline data not reported separately for dieters/non-dieters.	Unclear risk of bias
Allocation	Unclear. Possibly by diet centre attended.	Unclear risk of bias
Performance bias		
Blinding of participants and personnel	Not possible to blind participants to diet intervention. Blinding of study staff not reported. Comment: Probably not done. Potential impact on outcome unclear, but unlikely.	Low risk of bias

Study ID	Fabbricatore 2011b /cont.	
Detection bias		
Blinding of outcome assessment	Not applicable – all outcome measures self-reported	Not applicable
Attrition bias		
Incomplete outcome data	Not applicable – cross-sectional study	Not applicable
Reporting bias		
Selective reporting	All outcome measures reported	Low risk of bias
Other bias		
Other sources of bias	None	Not applicable

Study ID	Gilhooly 2007
Title	Food cravings and energy regulation: the characteristics of craved foods and their relationship with eating behaviors and weight change during 6 months of dietary energy restriction
Authors	Gilhooly CH, Das SK, Golden JK, McCrory MA, Dallal GE, Saltzman E, Kramer FM, Roberts SB.
Country	USA
Methods	DESIGN: Parent study – randomised controlled trial (CALERIE trial) with two active groups but data combined for the two groups and presented pre/post; cravings data used in this review – uncontrolled before and after data SAMPLING: Local advertisements INCLUSION CRITERIA: Adults, BMI 25–30 kg/m^2 EXCLUSION CRITERIA: Free of diseases that might affect outcome (e.g diabetes, cancer, CHD, endocrine disorder, psychiatric diagnosis,eating disorder); medication that could influence energy intake or metabolism; high dietary restraint (scores >17 on Eating Inventory); very high activity levels (>12 hrs/wk); inability to complete plausible 7-day dietary record; reported weight gain or loss >6.8 kg in previous year;

Study ID	Gilhooly 2007 /cont.
	anticipated lifestyle changes in following year. DURATION: Parent study 12 months; cravings data reported for first 6 months (subjects provided with all food and snacks during this period) DROPOUTS: 34 randomised; dropouts n=2/34 ANALYSIS: Paired *t*-tests for changes within subjects over time; independent *t*-tests and analysis of variance to assess any differences between randomisation groups (diet composition and energy restriction level); linear regression and Pearson correlation coefficients for relationships between food cravings and eating behaviour or BMI; multiple regression for predictors of weight loss.
Participants	N: 32 Demographic data not presented separately by diet group. AGE: 35.0 years WOMEN: 100% BMI: 27.8 kg/m^2 BODY FAT: 38.1%

Study ID	Gilhooly 2007 /cont.
Diet intervention	DIETS: (1) High glycaemic load (GL) – 60% carbohydrates, 20% fat, 20% protein, mean glycaemic index (GI) 86 and GL 116 g/1000 kcal; (2) low GL – 40% carbohydrates, 30% protein, 30% fat, mean GI 53 and GL 45 g/1000 kcal. Number assigned to each diet not reported. Diets matched for energy density, food variety, appearance, taste and smell. Also n=25 assigned to 30% calorie restriction and n=7 to 10% calorie restriction. CONTROL: Within subject – baseline versus 6 months ADHERENCE: Total energy expenditure measured using doubly labelled water at baseline, 3, 6, and 12 months. Energy intake calculated by correcting for change in body energy stores.
Outcomes	CRAVINGS MEASURES: Craving Questionnaire (Weingarten & Elston, 1991) and Food Craving Record (Hill et al., 1991) OTHER: Eating Inventory, 7-day food records

Study ID	Gilhooly 2007 /cont.	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Random sequence generation	Quote: "A block randomization stratified on body mass index, sex, and diet group was used." Method of randomisation not reported. Comment: probably random (within calorie restriction [CR] groups), given calibre of research centre. Comment: Somewhat over-stratified for sample size, although this was a pilot study designed to garner experience for conducting larger studies. Quote: "Twelve additional subjects were recruited and randomly assigned to 2 different control groups for the purpose of gaining experience in retaining a group control."	High risk of bias

Study ID	Gilhooly 2007 /cont.	
	Comment: 10% CR controls appear to have been recruited and randomised after the 30% CR group. 46 men and women recruited but cravings data presented for female members only (n=34) across all four diet interventions.	
Allocation concealment	Not reported	Unclear risk of bias
Performance bias		
Blinding of participants and personnel	Quote: "Subjects were not informed of their randomization until month 3 of calorie restriction." Comment: Blinding of study personnel not reported. Subjects provided with all food (four different diets) for the first six months. Study personnel probably not blinded to treatment condition; impact on outcome unclear.	Unclear risk of bias

Study ID	Gilhooly 2007 /cont.	
Detection bias		
Blinding of outcome assessment	Quote: "All outcome-assessment staff were blinded to participant randomization."	Low risk of bias
Attrition bias		
Incomplete outcome data	Comment: Analysis for completers only, but low drop-out rate: 2/34 (6%). Comment: Non-cravers (n=3/32 at baseline, 2/32 at 6 months) assigned zero values for frequency and intensity.	Low risk of bias
Reporting bias		
Selective reporting	All outcome measures reported	Low risk of bias
Other bias		
Other sources bias	None	Not applicable
Notes	Additional details of study protocol reported in Das et al. (2007)	

Study ID	Greenway 2010
Title	Effect of naltrexone plus bupropion on weight loss in overweight and obese adults (COR-I): a multi-centre, randomised, double-blind, placebo-controlled, phase 3 trial
Authors	Greenway FL, Fujioka K, Plodkowski RA, Mudaliar S, Guttadauria M, Erickson J, Kim DD, Dunayevich E, for the COR-I Study Group
Country	USA
Methods	DESIGN: Parent study – placebo-controlled randomised controlled trial (COR-I trial) of two doses of naltrexone versus placebo for weight loss; cravings data used in this review – placebo arm only, i.e. uncontrolled before and after data SAMPLING: Unclear INCLUSION CRITERIA: Age 18–65 years, BMI 30–45 kg/m^2 and uncomplicated obesity, or BMI 27–45 kg/m^2 and controlled hypertension or dyslipidaemia or both. EXCLUSION CRITERIA: Obesity of known endocrine origin; type I or II diabetes; cerebrovascular, cardiovascular, hepatic or renal disease; previous surgical or device intervention for obesity; loss/gain >4kg in 3 months prior to

Study ID	Greenway 2010 /cont.
	randomisation; history of seizures, psychiatric illness, use of study drugs in previous 12 months, drug or alcohol abuse in previous 12 months. DURATION: 56 weeks DROPOUTS: 581 randomised to placebo group; n=291/581 (50%) discontinued; most common reasons: withdrew consent (n=90), lost to follow-up (n=66), adverse events (n=56), insufficient weight loss (n=40). ANALYSIS: Least squares mean for change from baseline; based on primary analysis population (baseline plus at least one post-baseline reading, n=511); missing values imputed by last observation carried forward.
Participants	N: 511 AGE: 43.7 years WOMEN: 85% BMI: 36.2 kg/m^2 OTHER: 76% white; 11% current smokers; 19% hypertension; 50% dyslipidaemia

Study ID	Greenway 2010 /cont.	
Diet intervention	DIET: 500kcal/d caloric deficit based on WHO algorithm for calculating BMR, and advice on lifestyle modification CONTROL: Within subject – baseline versus 56 weeks ADHERENCE: Compliance with lifestyle modification (diet/exercise) not assessed.	
Outcomes	CRAVINGS MEASURES: Food Craving Inventory (White et al., 2002) and Control of Eating Questionnaire (COEQ) (Wilcox et al., 2010). Measurements taken at baseline, 8, 16, 28, and 56 weeks. OTHER: Body weight, clinical parameters	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Random sequence generation	Quote: "Randomisation was done by use of a centralised, computer-generated, web-based system and was stratified by study centre."	Low risk of bias
Allocation concealment	Quote: "Participant enrolment and assignment to trial groups was done by an automated system."	Low risk of bias

Study ID	Greenway 2010 /cont.	
Performance bias		
Blinding of participants and personnel	Quote: "Study site personnel, participants, and the study team were masked to treatment assignment; blinding was maintained apart from in an emergency. Active drug and placebo tablets were identical in appearance."	Low risk of bias
Detection bias		
Blinding of outcome assessment	As above	Low risk of bias
Attrition bias		
Incomplete outcome data	Quote: "The primary analysis population included all randomised participants with a baseline weight measurement and a post-baseline weight measurement while on study drug. Missing data were imputed by use of the last observation carried forward method."	Unclear risk of bias

Study ID	Greenway 2010 /cont.	
	Comment: 50% losses in each treatment group with differences in reasons for withdrawal. Time in study on withdrawal unclear. Impact on final analysis unclear.	
Reporting bias		
Selective reporting	Comment: Data from intermittent time points (wks 16, and 28) not reported. FCI scores not reported, only that they did not differ between drug and placebo groups. As this study compared drug vs placebo, this approach is not unreasonable, if not particularly helpful for current purposes.	Low risk of bias
Other bias		
Other sources of bias	None	Not applicable
Notes	Raw COEQ scores at baseline, week 8 and week 56 available in web appendix.	

Study ID	Harvey 1993
Title	Effects of food cravings of a very low calorie diet or a balanced low calorie diet
Authors	Harvey J, Wing RR, Mullen M
Country	USA
Methods	DESIGN: Parent study – randomised controlled trial with two active groups; cravings data used in this review – within-group, i.e. uncontrolled before and after data SAMPLING: Physician referral and recruitment through local newspapers INCLUSION CRITERIA: Age 30–70; ≥ 30% or 22.7 kg over ideal body weight based on 1983 Metropolitan Life Insurance Norms; Type II Diabetes EXCLUSION CRITERIA: Not reported DURATION: Parent trial –12 months. These data, nominally 6 months, but cravings only measure between baseline and week 18. Data grouped in 4 periods: week 1 (baseline), weeks 3, 5, 7 (first half of VLCD), weeks 9, 11, 13 (second half VLCD), weeks 15, 17, 19 (first half VLCD refeeding). DROPOUTS: 93 randomised; 13/93 did not complete the craving data at all 4 time points. Did not differ from

Study ID	Harvey 1993 /cont.
	completers in terms of baseline cravings or nutrient intake, but were younger and fatter than completers; similar numbers in both arms (6/48, 13% vs 7/45, 16%) did not complete. ANALYSIS: Cravings: repeated measures ANOVA, for each food separately and for the categories as a whole. Analysis (and demographic details) on PP population only. Craving scores reported as mean ± SD.
Participants	N: 80 (42 LCD, 38 VLCD) Demographic data presented separately by diet group but did not differ on any measure, or on energy/macronutrient intake. AGE: 52.8 years WOMEN: 65% BMI: 37.3 kg/m^2
Diet intervention	DIETS: (1) Low-calorie diet (LCD): a 'balanced 1000 to 1200 kcal diet throughout, calories spread throughout day, less than 30% calories from fat, 55-60% carbs, 10-15% protein (American Diabetes Association guidelines 1987). Advised on increasing complex carbs and fibre and reducing fat, but individual food choice up to participant;

Study ID	Harvey 1993 /cont.
	(2) Very low-calorie diet (VLCD): 400 to 500 kcal/day for weeks 1-12. Choice of Optifast 70 liquid formula or lean meat/fish/fowl, or a combination. Vitamin and mineral supplements. After 12 weeks, foods gradually introduced until reached 1000 to 1200 kcal/day by the fourth week, then maintained until next VLCD period. Both groups provided with weekly meetings, including training in diet, exercise and behaviour change. CONTROL: Within subject – baseline and three subsequent time points ADHERENCE: Self-monitoring books reviewed weekly. No data on level of compliance reported.
Outcomes	CRAVING MEASURES: Study-specific questionnaire; self-reported desire for 40 specified foods over previous 7 days; measured bi-weekly throughout the study. OTHER: Body weight and 3-day food records assessed at baseline and 6 months.

Study ID	Harvey 1993 /cont.	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Random sequence generation	Quote: "Eligible subjects were randomly assigned to the VLCD or LCD treatment group." Comment: Insufficient information to judge risk of bias.	Unclear risk of bias
Allocation concealment	Not reported	Unclear risk of bias
Performance bias		
Blinding of participants and personnel	Not reported. Comment: Not possible to blind participants with respect to LCD/VLCD. Unclear if staff delivering behavioural programmes were blinded – probably not done. Based on previously published work (discussed in introduction), staff	Unclear risk of bias

Study ID	Harvey 1993 /cont.	
	expectations of craving occurrence may have differed between the groups.	
Detection bias		
Blinding of outcome assessment	Not applicable – all outcome measures self-reported	Not applicable
Attrition bias		
Incomplete outcome data	Comment: Drop-outs were 12.5% in the LCD group and 15.6% in the VLCD group. Completers (data at all 4 time points) were significantly older and thinner than non-completers. Analysis for completers only.	High risk of bias.
Reporting bias		
Selective reporting	Comment: Data presented for each food type and group at all four time points.	Low risk of bias.

Study ID	Harvey 1993 /cont.	
Other bias		
Other sources of bias	Comment: Statistical analysis of ordinal data using the mean rather than median and may have skewed results to the left and/or hidden actual changes over time.	Unclear risk of bias.
Notes	Additional details of study protocol reported in Wing et al. (1994)	

Study ID	Lappalainen 1990
Title	Hunger/craving responses and reactivity to food stimuli during fasting and dieting
Authors	Lappalainen R, Sjödén P, Hursti T, Vesa V.
Country	Sweden
Methods	DESIGN: Parent study – non-randomised comparative study with two active groups; cravings data used in this review – within group, i.e. uncontrolled before and after data

Study ID	Lappalainen 1990 /cont.
	SAMPLING: Outpatients seeking and receiving treatment for overweight; unclear how study participants selected from all outpatients receiving treatment. INCLUSION CRITERIA: Not reported EXCLUSION CRITERIA: Not reported DURATION: 1 week baseline, 3 weeks intervention DROPOUTS: 5/18 (28%) did not follow protocol: 3/10 in fasting group (1 medical complications, 1 refused to participate in measures of food reactivity, 1 missing records at baseline) and 2/8 in dieting group (inability to follow dieting instructions or participate in test of reactivity to food stimuli. ANALYSIS: Data analysed on PP basis, i.e. 13/18 subjects included. Frequency of hunger/craving responses calculated as mean value/day. Intensity ratings excluded from analysis due to many missing values. Due to high mean differences in hunger responses between groups at baseline, hunger/craving differences between groups analysed by ANCOVA, with data from baseline as covariate.

Study ID	Lappalainen 1990 /cont.
Participants	N: 18 (Fasting group [FG] n=10; Dieting group [DG] n=8) Demographic data presented for all initial subjects; not reported separately for completers. AGE: 47.1 years WOMEN: 78% BMI: FG 32.1 kg/m^2, DG 35.3 kg/m^2 YEARS OVERWEIGHT: 17.1 OTHER: Two smokers in FG and one in DG. No significant differences in weight-treatment history.
Diet intervention	DIETS: (1) Low-calorie diet (n=6): Individual calorie levels set at beginning of treatment and guidance on food choice provided nutritionist-led group meeting/week, information and discussion about nutrition topics; (2) Fasting (n=7): Three day progressive reduction of calories: 800 to 200 kcal/d; 19 days at 200 kcal/d; 3 day progressive increase to 800 kcal/d. Subsequent 'normal' eating modified on basis of information received during treatment. Group meetings twice/week. CONTROL: Within subject – baseline and weekly for 3 weeks

Study ID	Lappalainen 1990 /cont.
	ADHERENCE: Changes in body weight and self-reported deviations from protocol used to estimate compliance. Results not reported, but mean weight loss was higher in fasting than dieting group at end of treatment (7.9 kg vs 2.0 kg, $p < 0.0001$), suggesting that groups differed in food consumption in expected manner.
Outcomes	CRAVINGS MEASURES: Study-specific recording sheet. Participants recorded incidence of hunger, cravings, or a combination of hunger+cravings as soon as possible after their occurrence, and rated intensity on a 100 mm VAS, with steps every 10 mm from 'none' to maximal. Time of day also recorded. Hunger defined as non-specific wanting due to energy deficit, often associated with discomfort, and relieved on consumption. Craving defined as specific desire, not related to energy deficit, associated with different sensation than hunger. Also associated with "seeking something pleasant, e.g. a pleasant mood." Participants instructed to read definitions including some examples, followed by verbal explanation, encouraged to ask questions, and record a couple of own examples to ensure understanding. Additional information required for fasting group. OTHER: Compliance (yes/no and nature of deviation) and reactivity to food stimuli once per week.

Study ID	Lappalainen 1990 /cont.	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Comparability of groups at baseline	Not applicable – different diet interventions considered separately in this review.	Not applicable
Allocation	Patient preference	High risk of bias
Performance bias		
Blinding of participants and personnel	Comment: Not possible to blind participants to diet intervention. Blinding of study personnel not reported. Comment: Probably not done.	Unclear risk of bias.

Study ID	Lappalainen 1990 /cont.	
Detection bias		
Blinding of outcome assessment	Not reported. Comment: Probably not done.	Unclear risk of bias.
Attrition bias		
Incomplete outcome data	3/10 patients in fasting group and 2/8 in dieting group withdrew and were excluded from the analysis. Withdrawals in fasting group largely unrelated to intervention. Withdrawals in dieting group more likely to be treatment-related. Patients asked to record frequency and intensity of hunger, cravings, and hunger/craving experiences, but only frequency data reported. Quote: "The intensity of feelings was excluded from the analysis because of many missing values." Comment: More likely to affect usefulness than validity of study findings.	High risk of bias in diet group. Low risk of bias in fasting group.

Study ID	Lappalainen 1990 /cont.	
Reporting bias		
Selective reporting	Except where stated above, measured outcomes reported.	Low risk of bias.
Other bias		
Other sources of bias	Comment: Definition of 'craving' included the concept that cravings were "associated with seeking for something pleasant, e.g. a pleasant mood." Not entirely consistent with other (later) literature on affective motivation. May have affected participants' understanding and reporting of cravings compared with other studies. Authors note additional information requirement for fasters may have reduced compliance with recording requirements and resulted in larger apparent decrease in craving frequency in FG.	Unclear risk of bias.

Study ID	Martin 2006
Title	Changes in food cravings during low-calorie and very-low-calorie diets
Authors	Martin CK, O'Neil PM, Pawlow L.
Country	USA
Methods	DESIGN: Parent study – non-randomised comparative study with two active groups; cravings data used in this review – within group, i.e. uncontrolled before and after data SAMPLING: Successive adult enrolees in two (LCD and VLCD) weight loss programmes at Medical University of South Carolina Weight Management Center. INCLUSION CRITERIA: Adult enrolees in above programmes; inclusion into VLCD programme required BMI ≥ 30 kg/m^2; completed a FCI at baseline (before dieting); attended at least one treatment session. EXCLUSION CRITERIA: Did not fill out FCI at baseline or attend at least one treatment session. DURATION: First 12 weeks used for this analysis as calorie intake in VLCD group was increased after 12 weeks. DROPOUTS: 18/39 LCD and 13/59 VLCD did not continue to week 12. No difference in any baseline craving, age or BMI scores between continuers or non-continuers.

Study ID	Martin 2006 /cont.
	A further 2/39 and 7/59 in the LCD and VLCD groups, respectively, did not provide craving data at week 12. Additional data were collected in the VLCD group at Week 6 of the refeeding phase, and a further 17 dropouts occurred before this time point. In the VLCD group, a larger proportion of women dropped out by Week 12 and refeeding Week 6. ANALYSIS: Data analysed on PP basis, i.e. 19/39 LCD subjects and 39/59 VLCD included at week 12, and 22/59 VLCD at refeeding Week 6. One-way ANOVA used for group differences at baseline on craving scores, BMI, weight and age; chi-squared analysis for between-group differences on gender and race distribution; Bonferroni adjustment used; one-way ANOVA for differences between completers and dropouts; ANCOVA for between-group differences in change over time, with baseline as covariate; for VLCD group, repeated-measures ANOVA for change between baseline, Week 6, Week 12, and refeeding Week 6; correlation analysis for association between weight loss and craving changes.

Study ID	Martin 2006 /cont.
Participants	N: 98 (LCD n=39; VLCD n=59) Demographic data presented for all initial subjects; not reported separately for completers. AGE: 45.2 years WOMEN: 74% BMI: LCD 35.1 kg/m^2, VLCD 45.0 kg/m^2 (p = 0.0001) OTHER: 87% Caucasian; no significant difference on baseline FCI scores.
Diet intervention	DIETS: (1) Low-calorie diet (n=19): ≥ 5024 kJ/d (~50% CHO, 20% protein, 30% fat); (2) Very-low calorie diet (n=22): Liquid supplement based plan, with optional one or two nutrition bars. Intake 3349 to 4187 kJ/d. Base diet 80g protein, 10g fat, 97g carbohydrate. Both groups offered weekly curriculum-based sessions promoting CBT techniques for diet/exercise change. But 8/59 VLCD and 2/39 LCD received these sessions on one-to-one basis. Weight-loss programme on a pay-per-service basis. CONTROL: Within subject – baseline and 12 weeks.

Study ID	Martin 2006 /cont.	
	ADHERENCE: Not reported	
Outcomes	CRAVINGS MEASURES: Food Craving Inventory (White et al., 2002) OTHER: Body weight at weekly sessions; variety index calculated for choice of supplement flavour in VLCD group.	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Comparability of groups at baseline	Between interventions: N/A – different diet interventions considered separately in this review. Within interventions: Based on personal preference 8/59 (14%) in VLCD participated on an individual basis whereas remainder attended group sessions. 2/39 (5%) in LCD group received personal treatment.	Unclear risk of bias in VLCD group. Low risk of bias in LCD group.
Allocation	Patient preference; also unclear if cost of programmes differed.	High risk of bias

Study ID	Martin 2006 /cont.	
Performance bias		
Blinding of participants and personnel	Comment: Not possible to blind participants to diet intervention. Blinding of study personnel not reported. Comment: Probably not done.	Unclear risk of bias.
Detection bias		
Blinding of outcome assessment	Craving outcome measures self-reported. Blinding of study staff not reported. Comment: Probably not done. Given expectations of craving experience with each diet, potential impact on outcome unclear, but unlikely.	Unclear risk of bias.
Attrition bias		
Incomplete outcome data	18/39 (46%) in the LCD group and 13/59 (22%) in the VLCD group dropped out before 12 weeks. A further 2 participants in LCD group and 7 in VLCD group did not complete craving measures at week 12. Non-completers excluded from analysis, so only 49% of the original LCD sample and 66% of the VLCD sample.	High risk of bias.

Study ID	Martin 2006 /cont.	
Reporting bias		
Selective reporting	All measured outcomes reported.	Low risk of bias.
Other bias		
Other sources of bias	None	Not applicable

Study ID	Martin 2011
Title	Change in food cravings, food preferences, and appetite during a low-carbohydrate and low-fat diet
Authors	Martin CK, Rosenbaum D, Han H, Geiselman PJ, Wyatt HR, Hill JO, Brill C, Bailer B, Miller, BV 3rd, Stein R, Klein S, Foster GD.
Country	USA
Methods	DESIGN: Parent study – randomised controlled trial with two active groups; cravings data used in this review – within group, i.e. uncontrolled before and after data

Study ID	Martin 2011 /cont.
	SAMPLING: Newspaper advertisements, flyers in university/hospital setting, physician referral, self-referral for weight-loss study INCLUSION CRITERIA: Age 18–65; BMI 30–40 kg/m^2; body weight < 136 kg EXCLUSION CRITERIA: Type II diabetes; blood pressure > 140/90 mm Hg; history of chronic disease or use of prescription/over-the-counter medications known to affect appetite, food intake or metabolism; smokers; vegetarians; dyslipidaemia medication, substance abuse; history of cardiovascular or protein wasting disease; pregnancy, lactating, or planning to become pregnant in next 2 years. DURATION: 2 years DROPOUTS: Details of missing data at individual time points 3, 6, 12, 18 and 24 months not provided in this study. Parent study reports between 6% and 42% attrition between 3 months and 24 months; however, any participant with baseline and at least one other craving score were included in this study – therefore only 12% excluded from 307 randomised in parent study.

Study ID	Martin 2011 /cont.
	ANALYSIS: Change from baseline at each time point. Randomly missing data imputed with likelihood-based method. Secondary analysis for participants with FCI values at 0 and 24 months (completers) and did not differ significantly from modified ITT. Correlation of change in cravings with change in body weight at each time point.
Participants	N: 270 (Low-carbohydrate diet [LCaD], n=134; Low-fat diet [LFD], n=136) AGE: 45.2 years WOMEN: 68% BMI: 36.0 kg/m^2 OTHER: 76% Caucasian, no difference in baseline craving or food preference scores.
Diet intervention	DIETS: (1) LCaD – unlimited consumption of fat/protein. Carb intake <20g/d for 3 months, then increase 5g/d/week; encouraged to follow guidelines in Atkins' New Diet Revolution book; (2) LFD – limit calorie intake and reduce fat intake; women initially prescribed 1200-1500 kcal/d and men 1500-1800 kcal/d. Encouraged to consume approx. 30% fat, 15% protein, 55% carbohydrates. Both groups received comprehensive empirically based behavioural treatment to foster dietary adherence.

Study ID	Martin 2011 /cont.	
	Weekly sessions for Weeks 1–20, bi-weekly Weeks 22–40, bi-monthly for Weeks 48–104. CONTROL: Within subject – baseline and five subsequent time points (3, 6, 12, 18, and 24 months) ADHERENCE: Not reported	
Outcomes	CRAVINGS MEASURES: Food Craving Inventory (White et al., 2002) at 0, 3, 6, 12, 18, 24 months OTHER: Food Preference Questionnaire, VAS of appetite ratings	
Risk of bias		
Domain	**Support for judgment**	**Judgment**
Selection bias		
Random sequence generation	Quote: "Using a random number generator, we randomly assigned participants within each site to treatment with either a low-carbohydrate or low-fat, calorie restricted diet for 2 years."	Low risk of bias
Allocation concealment	Not reported	Unclear risk of bias

Study ID	Martin 2011 /cont.	
Performance bias		
Blinding of participants and personnel	Not reported. Comment: Not possible to blind participants with respect to low-carbohydrate/low-fat diet. Behavioural programmes were delivered for each diet group independently. Sessions included review of diet records, therefore staff delivering programme also not blinded. Thorough, pre-determined session protocol. Staff expectations of cravings probably did not differ significantly for the two diet groups (differed on macronutrient composition only).	Low risk of bias
Detection bias		
Blinding of outcome assessment	Not reported	Unclear risk of bias

Study ID	Martin 2011 /cont.	
Attrition bias		
Incomplete outcome data	Comment: Modified intent-to-treat analysis used, including all participants with data at baseline and at least one other time point. Likelihood-based analysis for imputing data missing at random. Sensitivity analyses used to identify possible departures from randomness.	Low risk of bias
Reporting bias		
Selective reporting	All measured cravings outcomes reported for all time points.	Low risk of bias.
Other bias		
Other sources of bias	None	Not applicable
Notes	Additional details of study protocol reported in Foster et al. (2010)	

Appendix 3. Characteristics of excluded studies

Study ID	Reason for exclusion
Akkermann 2011	Not adults – adolescent girls
Alberts 2010, 2012	No non-diet control – mindfulness intervention
Benton 2010	Review
Berridge 2009	Review
Blumenthal 2010	Review
Bodenlos 2007	Not OW/OB – vagal nerve stimulation for depression
Brooks 2011	Review – cognitive bias to food stimuli in disordered eaters
Carr 1993	Animal study
Cartwright 2007	Not adults – paediatric population
Cartwright 2008	Not OW/OB – validation study OCQ in college students
Cepeda-Benito 2000	Not OW/OB – validation study FCQ-T/S in college students
Cepeda-Benito 2003	Not OW/OB – validation study FCQ-T/S in college students
Channon 1990	Not OW/OB; cravings not outcome – cue response
Cheah 2011	Not OW/OB; cravings not outcome – cue response
Coehlo 2006	Not OW/OB; cravings not outcome – cue response
Coehlo 2008	Not OW/OB; craving not outcome – effects of cue exposure on dietary restraint
Coehlo 2009a	Not OW/OB; cravings not outcome – cue reactivity

Study ID	Reason for exclusion
Coehlo 2009b	Not OW/OB; cravings not outcome – cue salience and consumption
Cohen 1987	Not OW/OB; Effect of mood and menses in restrained/non-restrained
Cornier 2010 (poster)	Weight unclear; cravings not outcome – cue reactivity
Corwin 2009	Review
Cowan 2008	Not OW/OB – recovering addicts
Curtis 2009 (poster)	Not dieting – food addiction
Dimitropoulos 2010	Craving not outcome – fMRI brain activation study
Drobes 2001	Not OW/OB ; cravings not outcome – cue reactivity with deprivation in restrained vs binge eaters
Du 1999	Animal study
El-Khatib 2007	Not OW/OB – valproate in epilepsy
Epstein 1961	Not OW/OB – cue response vs hunger
Evans 1999	Not OW/OB – drug effects on cravings vs premenstrual syndrome
Fedoroff 2003	Not OW/OB; cravings not outcome – cue reactivity in restrained/unrestrained eaters
Finlayson 2007a	Not dieting; craving not outcome – liking/wanting
Finlayson 2007b	Not OW/OB; craving not outcome – liking/wanting
Finlayson 2007c	Review
Finalyson 2008	Dieters excluded; craving not outcome – liking/wanting

Study ID	Reason for exclusion
Fletcher 2007	OW/OB not reported separately to NW; no separation between ever and current dieters
Forman 2007	Not dieting – interventions vs experimentally induced chocolate cravings
Forzano 1998	Cravings not outcome – cue exposure vs self control
Forzano 2010	Not dieting; cravings not outcome – cue exposure with deprivation vs self control and impulsiveness
Franchina 1988	Not OW/OB; not dieting – salivation in NW
Fulton 2002	Animal study
Gadde 2003	Cravings not outcome – pharmacologic weight loss study
Gearhardt 2011a	Review
Gearhardt 2011b	Cravings not outcome – MRI study vs high/low YFAS scores
Gendall 1997a	No separation between ever/current dieters; results not reported based on dieting condition
Gendall 1997b	Not OW/OB – anorexics
Gendall 1997c	Only reports ever-dieters, not current
Gendall 1998	Not dieting – psychiatric characteristics of cravers who binge vs non-bingers
Gibson 1999	Not OW/OB – chocolate cravings vs hunger in NW
Goldman 2010 (abs)	Not dieting – neurostimulation for cravings in healthy adults
Goldschmidt 2002	Weight / diet status unclear – cravings vs physical health

Study ID	Reason for exclusion
Goldstein 1970	Animal study
Gordon 1966	Not OW/OB; craving not outcome – cue response
Grothe 2008 (abs)	Not dieting – cravings vs inactivity
Hachl 2001	Not OW/OB; craving not outcome – response to food stimuli in restrained/unrestrained eaters
Harvey 2005	Weight not reported
Hawk 2004	Current dieters excluded
Hawks 2008	Review
Heller 1994	Review
Hetherington 1993	Cross-sectional data only; non-dieting control not OW/OB
Hetherington 1995 (abs)	Weight unclear; not dieting – chocolate addiction and hedonia
Hill 1991	Cravings vs dietary restraint, not current dieting
Hill 1994	Only 2/25 OW/OB; not dieting
Hill 2007	Review
Hooper 2012	Current dieters excluded
Hormes 2011	Measured dietary restraint; current dieting not reported
Hoyenga 1974	Animal study
Hoyenga 1982	Review
James 2004	Review
Juaregui Loera 2010	Weight unclear; not dieting – validation study of FCI
Juarascio 2011	Not dieting – validation study of FAAQ
Kemps 2004	Weight unclear

Study ID	Reason for exclusion
Kemps 2007	Not dieting
Kemps 2008	Effect of visual processing tasks on cravings; no pre-diet baseline for cravings
Kemps 2009	Dieting status unclear; craving not outcome – cue response
Kennedy 2010	Not dieting – hungry/fed; cravings not outcome – fMRI brain activation study
Komatsu 2008	Weight status unclear; not dieting – validation study of FCI-J
Landis 2008, 2009	Not adults – adolescents
Leland 2002, 2006	Weight unclear; not dieting; cravings not outcome – fasted cue response
Lemmens 2010	Not OW/OB – NW restrained/unrestrained eaters
Lemmens 2011	Not dieting; cravings not outcome – effects of stress on wanting and energy intake
Lim 2009	Not dieting – pre-diet study baseline data only
Martin 2000	Not dieting – pre-diet study baseline data only
Martin 2003a (abs)	Pharmacologic weight-loss study – implementation of dietary intervention unclear
Martin 2003b (abs)	Pharmacologic weight-loss study – implementation of dietary intervention unclear
Massey 2004, 2012	No pre-diet cravings data – group comparison OW dieters vs NW dieters and NW non-dieters

Study ID	Reason for exclusion
Mauler 2006	Not OW/OB; not dieting – deprivation in bulimics
McCrory 2010 (abs)	No pre-diet cravings data – effects of legume intake on cravings during dieting
Mercer 1997	Review
Meule 2011	Not OW/OB – effect of cravings on diet success in restrained/unrestrained eaters
Meule 2012a	Not OW/OB – cravings vs YFAS
Meule 2012b	Not OW/OB – validation German FCQ
Moreno 2006 (abs)	Not OW/OB - effects of fasting on cravings in bulimics
Moreno 2008	Not OW/OB – validation of FCQ in eating disorder patients
Moreno 2009	Not OW/OB – food cravings in anorexia and bulimia
Moreno-Dominguez 2012	Not dieting – high versus low chocolate cravers
Neithercott 2012	Review
Nijs 2007	Weight unclear; not dieting – validation of modified FCQ-T/S
Osman 2006	Not OW/OB – chocolate craving in Americans/Spanish
Pelchat 2004	Current dieters exclude
Pietrowsky 2003	Not OW/OB; not dieting; cravings not outcome – effect of deprivation on body dissatisfaction in restrained/unrestrained eaters
Polivy 2005	Not OW/OB; not dieting – effect of deprivation on cravings in restrained/unrestrained eaters

Study ID	Reason for exclusion
Polivy 2008	Review
Rejeski 2012	Current dieters excluded
Rodin 1991	Not OW/OB; not dieting – correlation of cravings with BMI, restraint, and oestradiol levels
Rogers 1989	Not OW/OB; not dieting – restraint vs hunger, salivation and food intake
Rosenbaum 2008	Cravings not outcome – response to food stimuli at reduced weight with/without leptin
Schlundt 1993	Not dieting – antecedents of cravings
Sitton 1991	No non-diet control – cravers vs non-cravers as predictor of weight loss intervention drop-out and weight loss; no measure of craving frequency/intensity.
Spence 1964	Weight unclear; not dieting; cravings not outcome – oral deprivation vs response to food stimuli
Steel 2006	Not OW/OB; not dieting – effects of hunger on experimentally induced cravings
Strachan 2004	Not OW/OB; not dieting – acute hypoglycaemia vs cravings in type 1 diabetics
Stuart 1962	Review
Teegarden 2004 (abs)	Animal study
Uher 2006	Not OW/OB; not dieting; cravings not outcome – effects of fasting on processing of food stimuli

Study ID	Reason for exclusion
Warren 1988	Not OW/OB – psychological effects of dieting in NW
Waters 2001	Not OW/OB – NW bulimics
Weingarten 1990	Review
Weingarten 1991a	Editorial
Weingarten 1991b	Weight and diet status unclear
Westman 2007	Review
White 2002	Weight and diet status unclear – validation of FCI
White 2005	Not dieting – validation of FCI in bingeing/non-bingeing
Yang 2010	Review

Abbreviations: FAAQ, Food cravings Acceptance and Action Questionnaire; FCI, Food Craving Inventory; FCI-J, Food Craving Inventory for Japanese; FCQ-T/S, Food Craving Questionnaire – Trait/State version; (f)MRI, (functional) magnetic resonance imaging; NW, normal weight; OB, obese; OCQ, Orientation to Chocolate Questionnaire; OW, overweight; YFAS, Yale Food Addiction Scale.

Other studies

Caballero 1987	Unable to obtain full-text copy
Vander Wal 2007	Potentially relevant data collected in this study but not reported in published paper. Authors have not responded to request for further information.
Wurtman 1987	Unable to obtain full-text copy
Wurtman 1990	Unable to obtain full-text copy
Zarcone 1997	Unable to locate this reference by author, title, or citation details

Appendix 4. Food craving questionnaires

Food Cravings Questionnaire – Trait (FCQ-T) (Cepeda-Benito, et al., 2000)

Validated 39-item scale loading on to nine factors: intention to eat craved foods (3 items: 5, 18, 23); anticipation of positive reinforcement (5 items: 9, 10, 15, 24, 38); anticipation of relief from negative states (3 items: 16, 19, 21); possible lack of control if food eaten (6 items); thoughts or preoccupations with food (7 items: 6, 8, 27, 28, 31, 32, 33); physiological response/hunger (4 items: 11, 12, 13, 14); emotions prior to or during cravings/eating (4 items: 20, 30, 34, 39); environmental triggers (4 items: 1, 35, 36, 37); guilt resulting from cravings or consumption (3 items: 4, 7, 17). No specific definition of the term 'craving' is used.

Subjects asked to rate each item:
"How frequently would each item be true for you, in general?"

Scored on a 6-point Likert scale:
1 = never/not applicable; 2 = rarely; 3 = sometimes; 4 = often; 5 = usually; 6 = always.

1. Being with someone who is eating often makes me hungry.
2. When I crave something, I know I won't be able to stop eating once I start.
3. If I eat what I am craving, I often lose control and eat too much.
4. I hate it when I give in to cravings.
5. Food cravings invariably make me think of ways to get what I want to eat.
6. I feel like I have food on my mind all the time.
7. I often feel guilty for craving certain foods.
8. I find myself preoccupied with food.
9. I eat to feel better.
10. Sometimes, eating makes things seem just perfect.
11. Thinking about my favourite foods makes my mouth water.

12. I crave foods when my stomach is empty.
13. I feel as if my body asks me for certain foods.
14. I get so hungry that my stomach seems like a bottomless pit.
15. Eating what I crave makes me feel better.
16. When I satisfy a craving I feel less depressed.
17. When I eat what I am craving I feel guilty about myself.
18. Whenever I have cravings, I find myself making plans to eat.
19. Eating calms me down.
20. I crave foods when I feel bored, angry, or sad.
21. I feel less anxious after I eat.
22. If I get what I am craving I cannot stop myself from eating it.
23. When I crave certain foods, I usually try to eat them as soon as I can.
24. When I eat what I crave I feel great.
25. I have no willpower to resist my food crave.
26. Once I start eating, I have trouble stopping.
27. I can't stop thinking about eating no matter how hard I try.
28. I spend a lot of time thinking about whatever it is I will eat next.
29. If I give in to a food craving, all control is lost.
30. When I'm stressed out, I crave food.
31. I daydream about food.
32. Whenever I have a food craving, I keep on thinking about eating until I actually eat the food.
33. If I am craving something, thoughts of eating it consume me.
34. My emotions often make me want to eat.
35. Whenever I got to a buffet I end up eating more than what I needed.
36. It is hard for me to resist the temptation to eat appetizing foods that are in my reach.
37. When I am with someone who is overeating, I usually overeat too.
38. When I eat food, I feel comforted.
39. I crave foods when I'm upset.

Food Craving Inventory (FCI) (M. A. White, et al., 2002)

Based on a similar approach to the 40-item questionnaire developed by Harvey et al (1993), but criticised food groupings in that earlier instrument, as well as clinical relevance of some items. Psychometric analysis identified four distinct subscales based on type of food, containing a total of 28 specific food items. A behavioural subscale investigating how often cravings were satisfied correlated very highly with the subjective scale and was deemed not to be measuring a unique construct, and was removed from the final version. A 'craving' was defined as "an intense desire to consume a particular food".

Subjects asked:
"Over the past month, how often have you experienced a craving for the food?"

Answers given on 5-point scale:
1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always/almost every day.

Forty food items were grouped *a priori* into five food types. Mean scores are generally presented for each food group.

- **High fats (8 items):** fried chicken, sausage, gravy, fried fish, bacon, corn bread, hot dog, steak.
- **Sweets (8 items):** brownies, cookies, candy, chocolate, donuts, cake, cinnamon rolls, ice cream.
- **Carbohydrates/starches (8 items):** rolls, pancakes/waffles, biscuits, sandwich bread, rice, baked potato, pasta, cereal.
- **Fast-food fats (4 items):** hamburger, French fries, chips, pizza.

Craving Questionnaire (Weingarten & Elston, 1991)

Collects demographic data (name, age, height, weight, gender) and current dieting status.
Please answer the following questions to the best of your ability.

1. Have you ever experienced food cravings (i.e. an intense desire to eat a specific food?)

   Yes No

2. If you have experienced food cravings, we would like to know what it is that you crave. List below foods that you crave, starting with your strongest craving. Beside each, estimate how often you experienced that craving.

CRAVED FOOD	FREQUENCY
Strongest craving: _____	_____ times/month
Next strongest (etc): _____	_____ times/month

3. The following questions refer only to the food which you indicated as your strongest craving (the food at the top of your craving list in Question 2).
   a. Describe in as much detail as you can the food you crave the most.
   b. When you are experiencing a craving for the food you crave the most, is there any other food which would satisfy that craving?
   c. When you experience a craving for the food you crave the most, how often do you follow through and eat that food?
   d. _____ % of the time
   e. (For women only) Do you feel that your cravings are related to your menstrual cycle?

      No Yes (If yes, then how?)

Is there anything about your cravings you would like to tell us that we forgot to ask?

Food Craving Record (A. J. Hill, et al., 1991)

Questionnaire made up of six questions assessing frequency, intensity, and definition of food cravings.

Responses to questions 1 to 5 recorded on 100 mm visual analogue scales (VAS); question 6 was descriptive. To avoid subjective definitions of the word 'cravings', this term was not used until the final question.

1. How often do you experience strong urges to eat particular types of food?
(VAS anchored with 'never' and 'all of the time')
2. On average, how often do you experience a strong urge to eat a particular type of food?
(VAS anchored with 'several times a day' and 'once a month')
3. How strong are these urges you experience to eat particular types of food?
(VAS anchored with 'extremely weak' and 'extremely strong')
4. Are the experiences of strong urges to eat a particular food always of the same strength?
(VAS anchored with 'never' and 'always')
5. How easy is it to ignore this strong urge to eat a particular food?
(VAS anchored with 'very easy' and 'impossible')
6. Is "a strong urge to eat a particular food" the same as "a craving for food"?
If not, in what was is it different?

Control of Eating Questionnaire (COEQ) (Wilcox et al., 2010)

Assesses hunger, fullness, desire for different types of food, mood and alertness, food cravings, and ability to resist cravings over previous 7 days. 21 items scored on 100 mm VAS (anchored 'Not at all ….' and 'Extremely …', unless otherwise stated. Food craving is defined as "a strong urge to eat a particular food or drink".

1. How hungry have you felt
2. How full have you felt
3. How strong was your desire to eat sweet foods
4. How strong was your desire for non-sweet tasty foods (French fries, potato chips, hamburgers, pizza)?
5. How happy have you felt?
6. How anxious have you felt?
7. How alert have you felt?
8. How contented have you felt?
9. During the last 7 days, how often have you had food cravings? (Not at all / Very often)
10. How strong have any food cravings been?
11. How difficult has it been to resist any food cravings?
12. How often have you eaten in response to food cravings? (Not at all / After every one)

How often have you had cravings for the following: (Not at all / Extremely often)

13. Chocolate or chocolate flavoured foods?
14. Other sweet foods (cakes, pastries, chocolate, etc)?
15. Fruit or fruit juice?
16. Dairy foods (cheese, yogurts, milk, etc.)?
17. Starchy foods (bread, rice, pasta, etc.)?
18. Tasty foods that are not sweet (French fries, potato chips, burgers, pizza, etc.)?
19. Generally how difficult has it been to control your eating?
20. Which one food makes it most difficult for you to control eating?
21. How difficult has it been to resist eating this food during the last 7 days?

Study-specific questionnaire (Lappalainen, et al., 1990)

Patients recorded the frequency and intensity of hunger, craving, and a 'combination' feeling (hunger and craving at the same time) on a recording sheet.

Hunger was defined as a general desire to eat or drink related to an energy deficit (no specific food item intended). Craving was defined as a desire to consume a specific food item or drink not related to a deficit of energy, and connected with a different kind of feeling than when hungry. The feeling of craving was defined as associated with seeking for something pleasant, e.g. a pleasant mood.

Patients were instructed to make their recordings as soon as possible after they had experienced hunger and/or cravings, using the letters 'H' for hunger, 'S' for craving (based on Swedish word for craving), and 'X' for a combination feeling. Intensity was to be reported on a scale from 0 to 100 including 11 steps (from 'none' to 'maximal', with steps at 10, 20, etc.). Time of day was also recorded.

The fasting group were additionally required to record the thought that elicited the feeling, what they wanted to eat or drink, what they actually did to cope with the feeling, and the duration of the feeling.

Study-specific questionnaire (Harvey, et al., 1993)

Subjects were asked:

"At times we all have cravings or desires to eat particular foods. During the past week, to what degree have you wanted to eat the following foods?"

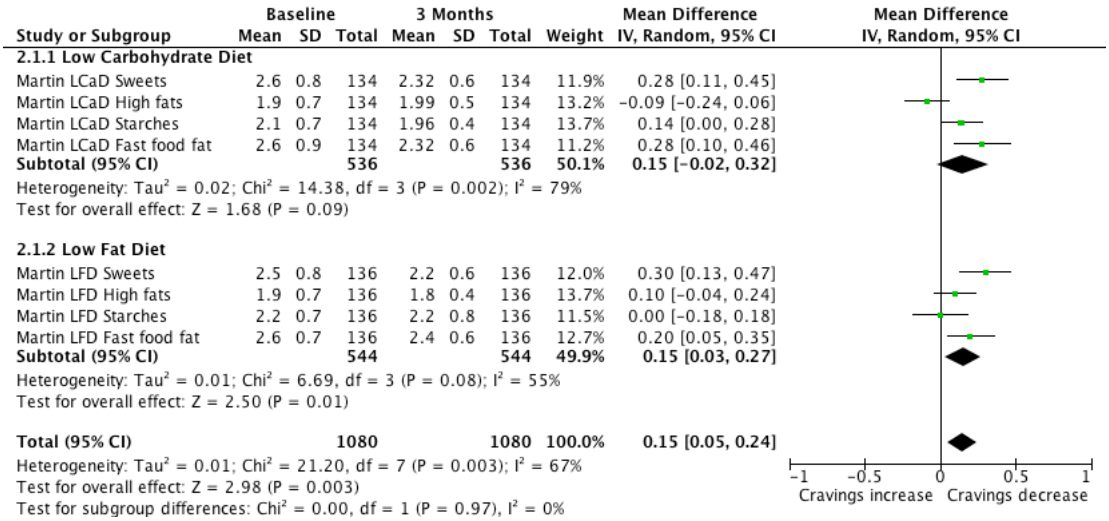
Answers given on 5-point scale:

1 = not at all; 2 = a little; 3 = somewhat; 4 = pretty much; 5 = very much.

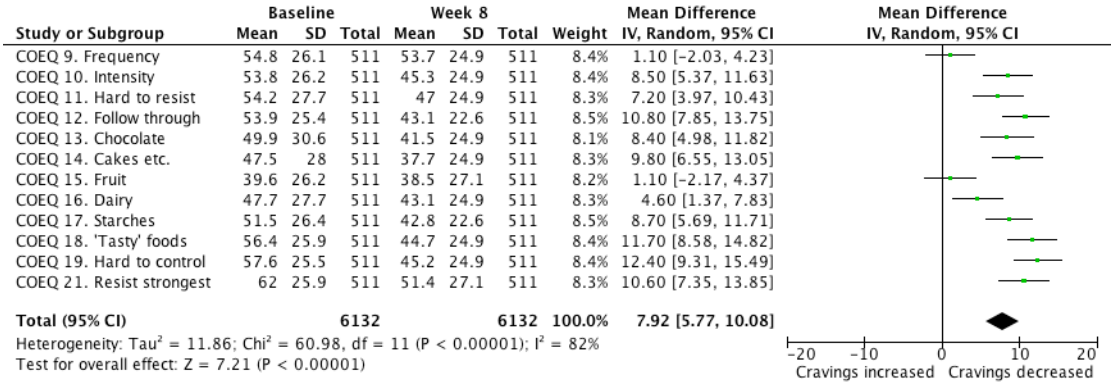
Forty food items were grouped *a priori* into five food types. It is unclear what order the items were presented on the questionnaire and whether they were arranged by group or at random. Mean scores are presented for individual foodstuffs and for each food group.

- **Low-fat protein (8 items):** broiled fish, shrimp, roasted or broiled chicken, lean beef, turkey, veal, tuna fish, skimmed milk.
- **High-fat protein (8 items):** steak, hot dog, barbequed ribs, fried chicken, sausage or bacon, fried fish, whole milk, cheese.
- **Complex carbohydrates (10 items):** bread, white bread, cereal, rice, spaghetti, cooked vegetables, raw vegetables, other cooked, baked potato, raw fruit.
- **Other fats (8 items):** French fries, cake/donuts/cookies, pie, chocolate candy, ice cream, milk shake, butter/margarine, gravy.
- **Miscellaneous (6 items):** canned fruit, fruit juices, hard candy, salty snacks/pretzels, crackers, peanuts.

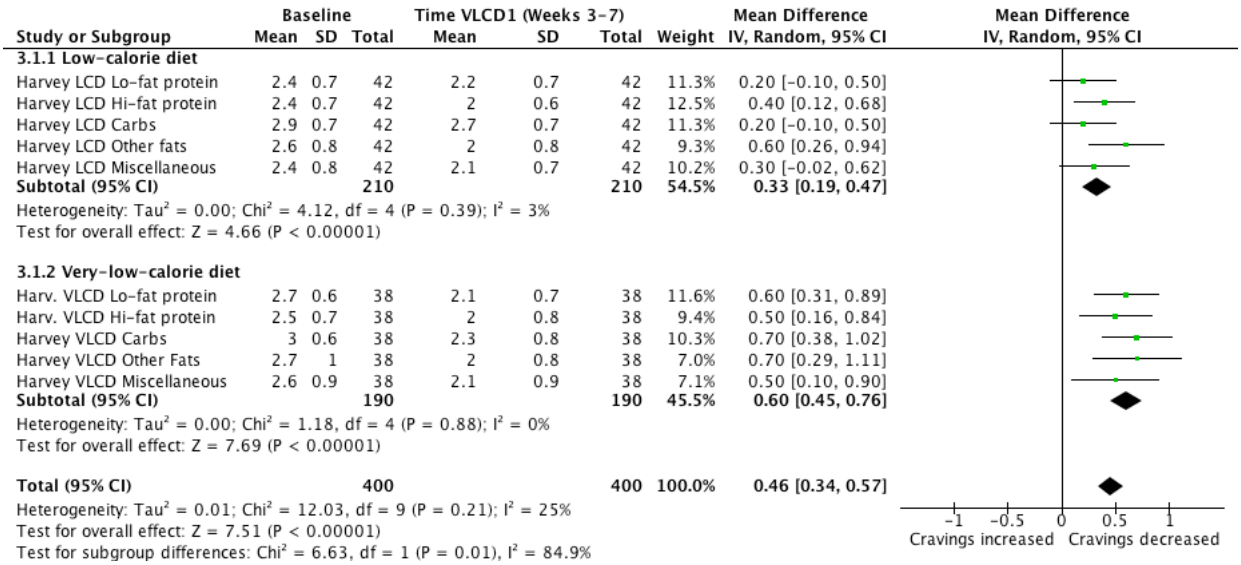
Appendix 5. Forest plots



A5 Figure A1. Change in FCI scores between baseline and 3 month – Martin et al., 2011



A5 Figure A2. Change in COEQ scores between baseline and Week 8 - Greenway et al., 2010



A5 Figure A3. Change in craving scores between baseline and time period VLCD1 (mean values weeks 3, 5 and 7) - Harvey et al., 1993